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DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF ILLINOIS

MAY 28, 1951

VOLUME I - TEXT

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK PHILADELPHIA CHICAGO LOS ANGELES

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LETTER OF TRANSMITTAL

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Engineers

NEW YORK
CHICAGO

CONSTRUCTION VALUATIONS REPORTS MANAGEMENT

PHILADELPHIA
LOS ANGELES

39 BROADWAY
NEW YORK 6

New York, May 28, 1951

The Chief of Engineers
Department of the Army
Washington 25, D.C.

Dear Sir:

We submit herewith our report upon "The Synthetic Liquid Fuel Potential of Illinois", in accordance with Contract No. W 49-129 eng-137 concluded between us May 3, 1949.

Our survey disclosed widespread interest in synthetic liquid fuels. Informed public opinion recognizes the need for utilizing to the utmost all possible resources for the maintenance of our national welfare and security. Both public and private agencies have been very helpful in supplying data and entering into frank discussions with us on the subject. We welcome this opportunity to thank them for their cooperation.

Supplies of crude petroleum, the source of liquid fuels, are not inexhaustible. Provision must be made for the day when such fuel reserves become dangerously low. Foresight is required of all of us in facing this problem.

Over-all requirements of our natural resources are constantly changing. Obviously, no survey can do more than describe conditions in the light of present knowledge.

We believe that this report will be of value in formulating policy with respect to the future development of synthetic liquid fuels.

Our attached report is submitted in two volumes: Volume I contains the text and Volume II contains the exhibits and appendices.

Very truly yours,

(Signed) Ford, Bacon & Davis, Inc.

REPORT

IDENTIFICATION OF GENERAL AREAS

No.	General Areas
1	Southeastern Grundy
2	La Salle-Grundy
3	Bureau-Putnam
4	Henry No. 6
5	Northern Knox
6	Marshall
7	Peoria
8	Fulton-Knox
9	Vermilion
10	Logan
11	Macon
12	Menard
13	Sangamon
14	Northern Christian
15	Southeastern Montgomery
16	Maccupin
17	Madison
18	Bond
19	Clinton
20	Marion
21	Clay
22	Wayne
23	Jefferson
24	Washington
25	St. Clair
26	Randolph
27	Perry
28	Franklin
29	Jackson No. 5
30	Williamson
31	Saline

SCALE OF MILES
10 0 10 20 30 40

REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
ILLINOIS
LOCATION OF
SUITABLE GENERAL AREAS
FOR
SYNTHETIC LIQUID FUEL MANUFACTURE

Ford, Bacon & Davis
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Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

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WARREN
IROQUOIS
Galesburg
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Danville
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MORGAN
SANGAMON
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Cairo
Paducah

Lake Michigan
Chicago
Des Plaines River
Kankakee River
Vermilion River
Illinois River
Mississippi River
Sangamon River
South Fork
Middle Fork Vermilion River
Wabash River
Little Wabash River
Kaskaskia River
Embarrass River
Missouri R.
Big Muddy R.
Ohio River

SF-136 1-9-51

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF ILLINOIS

MAY 28, 1951

SUMMARY

Introduction

The Department of the Interior, as part of its broad program of synthetic liquid fuels research, requested the Department of the Army in 1947 to assist in the development of the synthetic liquid fuels program. This investigation and report on Illinois are in part fulfillment of a contract to that effect awarded by the Corps of Engineers of the Department of the Army. The contract calls for a survey of 37 states and Alaska to determine Suitable General Areas and their potential capacity for the production of synthetic liquid fuels from coal, natural gas, oil shale, and oil-impregnated strippable deposits.

The General Areas containing raw materials and water supply of proper quantity and quality required by synthetic liquid fuels plants and various economic factors further affecting the suitability of such Areas for plant location are critically examined. No core drillings, extensive sampling or detailed field examinations were made and studies are based on information now available. Suitable General Areas, as indicated on the map on the facing page, were determined and defined but no specific plant sites are selected.

Raw Materials

The raw materials considered in this survey of Illinois are coal, natural gas,and oil shale. No report was authorized in relation to oil-impregnated strippable deposits because it was considered that known deposits in Illinois of such raw materials were of doubtful economic importance.

Coal. Of the raw materials considered in Illinois, coal is by far the most abundant and available. It is found to be the only raw material meeting the survey requirements for synthetic liquid fuels production.

Natural Gas. The total reserves of natural gas in Illinois as of January 1, 1949, are estimated at 241,927,000 Mcf with a heating value in the order of 1,100 Btu per cubic foot under standard conditions. Most of Illinois' gas reserves are either under contract to be processed by gasoline plants in the State (the residue gas, after processing, being likewise under contract) or will be used in local field operations. Consequently, only 13,054,000 Mcf remaining undedicated could be considered available to meet the survey requirements which call for undedicated deposits containing, within a radius of 40 miles, at least 225 trillion Btu (about 204,500,000 Mcf of 1,100-Btu gas) with a heating value of at least 400 Btu per cubic foot under standard conditions.

Oil Shale. Although deposits of oil shale occur at numerous locations in Illinois, there are no deposits known to be of sufficient extent or rich enough to meet the survey's minimum reserve requirements of 100,000,000 tons within a 5-square-mile area, yielding an average of 15 gallons of oil per ton, in beds at least 25 feet thick.

General Features

Illinois, averaging about 550 feet in elevation, consists mainly of level or slightly undulating plains. A rich and quite fertile black loam or mold, underlain by deep drift deposits, forms the soil with alluvial material common in the river valleys. The surface rises to ranges of low hills in the northwestern and southern sectors and there are occasional bluffs along the Illinois and Mississippi Rivers. The water courses flow generally from the north and northeast to the south and southwest. In the areas underlain by coal, there are ample water resources. The climate is generally mild with medium precipitation.

The 1950 population density averages 155 per square mile throughout the 55,947 square miles of land area of the State. In the portion of the State containing raw materials suitable for synthetic liquid fuels production, comprising 35 major coal-producing counties with a total area of 21,227 square miles, a population density of 83 results from a 1950 population of 1,769,333.

Although approximately 10 percent of the total labor force in 1940 was engaged in farm work, the economy of the State is primarily industrial. Principal industries include meat packing, iron and steel, tractors and agricultural machinery, printing and publishing, petroleum refining, and the manufacture of electrical equipment, metal containers, and motor vehicles.

Excellent transportation facilities are provided by 68 railroads with a total trackage in the State exceeding 12,000 miles. Water transportation by freighters and barge lines is available on the Great Lakes and many rivers including the Mississippi, Illinois, and Ohio, as well as to southern points via canals connecting Lake Michigan with the Illinois and Mississippi Rivers. When synthetic liquid fuels are required, plants in the Illinois General Areas would be well situated for the distribution of their products within the defined marketing territory.

Processes

Since coal is found to be the only raw material available in requisite quantity, only two processes of synthetic liquid fuels manufacture are considered; namely, hydrogenation and the synthine process.

In hydrogenation, coal is liquefied by combination with hydrogen at high pressures and temperatures in the presence of a catalyst. In the synthine process, coal is first converted to a gaseous mixture of carbon monoxide and hydrogen, which gases, in the presence of a suitable catalyst, combine to form liquid fuels. Both processes require major quantities of coal for direct conversion to liquid fuels and to provide energy for such conversion, and of water, chiefly as a cooling medium. The unit plant size adopted in the survey as a basis for estimates for comparison is 10,000-barrel-per-day capacity.

As a synthetic fuels program of any magnitude would necessarily require a considerable period of years for its realization, estimates of unit quantities of raw materials required and unit costs of plant construction and operation, used in this survey for determining ultimate production potential and relative desirability of the various General Areas, have been based on the assumed use of certain improvements in equipment and process which are still under

development but which seem reasonably likely to be available by the time such a program could be well under way. Moreover, the estimated data and costs for the coal synthine process have been taken from preliminary studies made by the U. S. Bureau of Mines for a report which is not yet completed. The final estimates of the Bureau, when available, may differ materially from these preliminary figures. While the data used have been selected as offering a fair basis for comparison, it must be understood that if synthetic fuels plants were to be built at the present day, using only equipment and processes already commercially available, coal requirements and plant and product costs might be appreciably higher than those shown in this report.

Subject to the above comments, daily requirements of Illinois coals, as received at the synthetic liquid fuels plants, should average about 4,450 tons for a hydrogenation unit plant and about 5,720 tons for a coal synthine unit plant.

General Areas of Coal Availability

Coal-bearing formations solidly underlie approximately the southern three-quarters of Illinois, except for narrow marginal areas along the Mississippi, Ohio, and lower Illinois Rivers. They occupy an area of about 36,800 square miles including all or parts of 84 counties. All coal beds of Illinois belong to the Pennsylvanian system which is here commonly divided into the basal Pottsville, the intermediate Carbondale, and the upper McLeansboro formations. At least 16 coal beds are known, of which 5 have been mined over relatively large areas while the remainder have been mined only in local areas of limited thickening. Of the 84 coal-bearing counties, 6 contain coal deposits which are too close to the outermost edge of the coal-bearing formations to contain appreciable minable areas. In 25 other counties, the reserves are either isolated and insufficient in amount or are without adequate available information to permit estimation of reserves. As a result, these 25 counties were also eliminated from further consideration.

The 53 remaining counties contain reserves satisfactory for synthetic liquid fuels production. These counties contain 31 areas, each not larger than a county or 1,000 square miles, each of which contains adequate coal reserves for a 40-year supply of at least one 10,000-barrel-per-day synthetic liquid fuels plant. Identified by the names of the counties in which important portions lie, these 31 General Areas of Coal Availability in Illinois are, from north to south:

1. Southeastern Grundy
2. La Salle-Grundy
3. Bureau-Putnam
4. Henry No. 6
5. Northern Knox
6. Marshall
7. Peoria
8. Fulton-Knox
9. Vermilion
10. Logan
11. Macon
12. Menard
13. Sangamon
14. Northern Christian
15. Southeastern Montgomery
16. Macoupin
17. Madison
18. Bond
19. Clinton
20. Marion
21. Clay
22. Wayne
23. Jefferson
24. Washington
25. St. Clair
26. Randolph
27. Perry
28. Franklin
29. Jackson No. 5
30. Williamson
31. Saline

The total tonnage of coal considered for synthetic liquid fuels production in Illinois as of January 1, 1950, based on available information and within the limits of reserves specified by this survey as described in Part II of this report under "Survey Specifications" and in Part IV under "Survey Methods and Procedure" was estimated at 49,633,725,000 tons in place. Of this tonnage, 24,867,174,000 tons were estimated as being recoverable. These estimates are, therefore, not comparable with other coal estimates which generally include the total coal reserves in Illinois without the limitations imposed by this survey. For example, in Circular 94 of the U. S. Geological Survey, the total recoverable reserves for Illinois, as of January 1, 1950 (assuming 50 percent recovery) are reported to be 82,820,503,000 tons. This estimate of the Geological Survey adopts a 1946 estimate by Cady, in turn for the most part based on estimates of Cady, Culver, Kay and White published in 1925 or earlier.

After giving consideration to isolated areas with insufficient reserves to provide at least one synthetic liquid fuels unit plant, to commercial requirements over the next 50 years, and further contract limitations as to the use of primary and secondary reserves, the total tonnage of coal recoverable and available for the manufacture of synthetic liquid fuels in the 31 General Areas of Illinois was estimated to be 15,356,946,000 tons. Of this total, 15,055,076,000 tons are recoverable by underground mining methods. 301,870,000 tons are classified as "strippable" under the definitions described under "Survey Specifications" and "Survey Methods and Procedure".

The following table lists, for each of the 31 General Areas the recoverable coal reserves, the average heating value of the coal, and the potential synthetic liquid fuels production in total and as a daily average over a 40-year period. These estimates assume the use of either the hydrogenation process or the synthine process; but the potential production is not additive.

Potential Synthetic Liquid Fuels Production from Available Coal Reserves, in Total and as a Daily Average over 40 Years for each General Area of Illinois

(As of January 1, 1950)

General Area	Recoverable Coal Reserves (1,000 tons)	Average Btu Value	Potential Production: Total in Million Barrels		Potential Production: Average Daily in Thousand Barrels	
			Hydrogenation	Coal Synthine	Hydrogenation	Coal Synthine
Macoupin	1,866,874	10,740	4,092	3,183	280	218
Sangamon	1,612,940(A)	10,660	3,509	2,729	240	187
Southeastern Montgomery	1,220,676(A)	10,760	2,681	2,085	184	143
Perry	1,022,846(A)	11,290	2,357	1,833	161	125
St. Clair	919,120	10,980	2,060	1,602	141	110
Northern Christian	899,764(A)	10,870	1,996	1,552	137	106
Saline	801,624(A)	12,310	2,014	1,566	138	107
Clinton	726,830(A)	10,870	1,612	1,254	110	86
Franklin	673,788(A)	11,830	1,627	1,265	111	87
Jefferson	519,496(A)	11,980	1,270	988	87	68
Madison	450,006(A)	10,750	987	768	68	53
Peoria	443,432(A)	10,700	968	753	67	51
Williamson	424,470(A)	11,910	1,032	802	71	55
Vermilion	360,419	10,910	802	624	55	43
Randolph	325,119	11,020	731	569	50	39
Jackson No. 5	306,208	11,670	729	567	50	39
Menard	303,476(A)	10,730	665	517	46	35
Wayne	289,496(A)	11,440	676	526	46	36
Fulton-Knox	259,500(A)	10,450	553	430	38	29
Bureau-Putnam	219,805	11,040	495	385	34	26
Henry No. 6	217,734	10,040	446	347	31	24
Bond	207,712(A)	10,800	458	356	31	24
Washington	204,296(A)	11,000	459	357	31	24
Macon	184,654(A)	10,700	403	314	28	21
Logan	179,544(A)	10,750	394	306	27	21
La Salle-Grundy	172,265	11,070	389	303	27	21
Marion	139,100	11,200	318	247	22	17
Clay	123,022(A)	11,370	285	222	20	15
Northern Knox	113,974	10,200	237	185	16	13
Southeastern Grundy	104,196	11,130	237	184	16	13
Marshall	64,560	11,300	149	116	10	8
Total	15,356,946		34,631	26,935	2,373	1,844

Note: (A) Primary and secondary coal reserves for synthetic liquid fuels plant supply in any General Area are limited by definition to twice the primary reserves of the Area.

The foregoing reserves are contained in four coal beds, Nos. 2, 5, 6, and 7, varying in rank from high-volatile A to high-volatile C bituminous. Ranges in selected items of representative analyses (selected by the Coal Subcontractor from available analyses, mostly mine samples, as representative of the coal reserves or beds under consideration), of the four beds containing coal reserves, are as follows:

Representative Analyses of Coal Reserves
Face Samples (as-received basis) in 31 General Areas

	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Bed No. [illegible] (1 General Area only)	14.2%	10.4%	2.8%	10,910
Bed No. 6:				
Maximum	18.5	11.8	4.2	12,580
Minimum	4.3	8.7	1.3	9,750
Bed No. 5:				
Maximum	15.4	11.1	4.5	12,610
Minimum	4.5	8.7	2.6	10,420
Bed No. 2:				
Maximum	17.1	8.6	4.9	11,340
Minimum	13.7	5.1	1.6	10,900

The U. S. Bureau of Mines has published the results of petrographic analyses of Illinois coals from 7 of the counties and 3 of the coal beds considered in the 31 Suitable General Areas of Illinois. The results indicate these coals to be of the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain (difficult to liquefy) being present in minor amounts. Since all of the coals of the 31 General Areas are closely similar in rank and in visual and chemical composition to the coals for which petrographic analyses have been reported, there is no reason to expect any substantial differences in the degree of heterogeneity or adaptability to hydrogenation of the Illinois coals.

Publications of the Illinois Geological Survey contain relatively comprehensive information on organic and inorganic sulfur contents of representative Illinois coals. In general, organic sulfur, which is not considered amenable to reduction by mechanical cleaning, averages approximately 42 percent of the total sulfur content or from about 0.6 to 2.0 percent in the coal. Further study of these coals is necessary to evaluate the reduction in total sulfur which might result from mechanical cleaning.

Weathering and slacking characteristics are similar to those of other coals of the same rank; that is, the coals do not usually slack readily or ignite spontaneously when exposed to air, although midwestern coals are generally more susceptible to spontaneous combustion than Appalachian coals. When properly stored, however, there is no problem of spontaneous combustion.

Coal of Bed No. 7 is free from persistent partings but is characterized by the frequent occurrence of lenses of shale or pyrite. A parting known as the "blue band" is persistent in Bed No. 6 and a second and somewhat higher shale parting is often found. Frequent small lenses of shale or pyrite occur in this bed in the northern part of the State. Bed No. 5 is typically free of persistent interbedded partings, especially in southern Illinois. No. 2 bed does not contain any persistent bedded partings and is generally uniform in thickness and physical characteristics within the areas of occurrence.

The greater Btu input requirement for coal synthine plants, as compared with hydrogenation, results in larger quantities and thus higher total costs of coal supply. Estimated capital costs to provide coal mining facilities for underground mining range, in Illinois, between the following minimum and maximum for a unit plant using the indicated process:

Tonnage of Coal Required and
Ranges in Capital Cost of Coal Supply for
10,000-barrel-per-day Unit Plants

	Suitable General Areas	
	Saline	Henry No. 6
Hydrogenation Process		
Daily Production, Tons (240 days per year	6,054	7,416
Capital Costs (underground mining):		
Maximum		$ 8,010,000
Minimum	$5,957,000	
Coal Synthine Process		
Daily Production, Tons (240 days per year)	7,784	9,534
Capital Costs (underground mining):		
Maximum		$10,296,000
Minimum	$7,659,000	

Factors influencing these costs include depth and character of coal bed and associated strata, and also the quantity and quality of the coal. The cost estimates provide for all necessary structures and mine operating equipment, facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, as well as for mechanical cleaning to produce merchantable coal, waste disposal from the cleaning of raw coal, surge storage at the mine, engineering, development, and contingencies.

Costs of supplying coal range, for underground mining, from a minimum of $3.23 per ton (15.04¢ per million Btu) to a maximum of $5.51 per ton (24.08¢ per million Btu) in the 31 Suitable General Areas. Variations in cost result from differences in mining characteristics, in nature of the beds and partings in the beds, and in calorific value of the coals. The calorific value of the coals, the productivity, and the estimated cost of production, after making allowances for variations in preparation costs, are shown below. All costs are for coal produced by underground mining, and are exclusive of return on investment and of selling expense.

Estimated Coal Production Costs for Underground Mining in General Areas in Illinois
(As of March 31, 1950)

Suitable General Area	Btu Per Pound	Tons Per Man-shift	Dollars Per Ton	Cents Per Million Btu	Dollars Per Barrel of Products: Hydro-genation	Dollars Per Barrel of Products: Syn-thine
Macoupin	10,740	12	$3.23	15.04¢	$1.47	$1.90
Northern Christian	10,870	12	3.24	14.90	1.46	1.88
Southeastern Montgomery	10,760	12	3.24	15.06	1.48	1.90
St. Clair	10,980	11	3.39	15.44	1.51	1.95
Randolph	11,030	11	3.39	15.37	1.51	1.94
Perry	11,290	11	3.39	15.01	1.47	1.89
Franklin	11,830	11	3.39	14.33	1.40	1.81
Logan	10,750	10	3.58	16.65	1.63	2.10
Macon	10,700	10	3.58	16.73	1.64	2.11
Menard	10,730	10	3.58	16.68	1.63	2.10
Sangamon	10,660	10	3.58	16.79	1.65	2.12
Williamson	11,910	10	3.58	15.03	1.47	1.89
Saline	12,310	10	3.58	14.54	1.42	1.83
Madison	10,750	9	3.81	17.72	1.74	2.23
Jefferson	11,980	9	3.81	15.90	1.56	2.00
Bond	10,800	9	3.83	17.73	1.74	2.23
Washington	11,000	9	3.83	17.41	1.71	2.19
Jackson No. 5	11,670	7	4.40	18.85	1.85	2.38
Peoria	10,700	7	4.44	20.75	2.03	2.61
Fulton-Knox	10,450	7	4.44	21.24	2.08	2.68
Vermilion	10,910	7	4.44	20.35	1.99	2.56
Clinton	10,870	7	4.44	20.42	2.00	2.57
Marion	11,200	7	4.44	19.82	1.94	2.50
Henry No. 6	10,050	7	4.46	22.19	2.17	2.80
Northern Knox	10,200	7	4.46	21.86	2.14	2.75
Southeastern Grundy	11,130	5	5.46	24.53	2.40	3.09
La Salle-Grundy	11,070	5	5.48	24.75	2.43	3.12
Bureau-Putnam	11,040	5	5.48	24.82	2.43	3.13
Marshall	11,300	5	5.48	24.25	2.38	3.06
Clay	11,370	5	5.51	24.23	2.37	3.05
Wayne	11,440	5	5.51	24.08	2.36	3.03

It is to be noted that in five of the General Areas of Illinois where there are appreciable reserves of coal minable by strip-mining methods available for an initial unit plant in the Area, small differences are estimated for calorific values, assuming priority use of the strip coal, and for coal costs - per ton, per million Btu, and per barrel of products. Such estimates, applicable only to initial unit plants in the Areas concerned, are as follows:

Estimated Coal Production Costs for Initial Unit Plants in General Areas Having Strippable Coal
(As of March 31, 1950)

Suitable General Area	Btu Per Pound	Tons Per Man-shift	Dollars Per Ton	Cents Per Million Btu	Dollars Per Barrel of Products
Hydrogenation Process:					
Peoria (A)	10,680	25	$2.68	12.55¢	$1.23
Northern Knox (A)	10,200	25	2.70	13.24	1.30
Perry (A)	11,305	20	2.95	13.05	1.28
Randolph (B)	10,980	18.4	2.97	13.52	1.32
Henry No. 6 (B)	10,020	10.6	4.03	20.11	1.97
Coal Synthine Process:					
Peoria (A)	10,680	25	$2.68	12.55¢	$1.58
Perry (A)	11,305	20	2.95	13.05	1.64
Randolph (B)	10,990	16.6	3.06	13.92	1.75
Northern Knox (B)	10,200	21	3.09	15.15	1.91
Henry No. 6 (B)	10,020	9.9	4.12	20.56	2.59

Note: (A) All strippable coal.
(B) Partly strippable and partly underground coal.

General Areas of Coal and Water Availability

Investigation of potential sources for the large quantities of water required for synthetic liquid fuels plants shows that there is available, in excess of known and proposed water uses, enough water in the Mississippi, Illinois, Ohio, or Wabash Rivers and their tributaries, or from Lake Michigan or underground sources to supply all the production capacity for which coal is available. Water required for full development in each Suitable General Area. ranges from 16 cubic feet per second (cfs) in the Marshall General Area to 441 cfs in the Macoupin General Area. The total water required for complete development in all General Areas would be 3,734 cfs or 2,414 million gallons per day (mgd).

Estimates of water quantities and costs are based upon the greater requirements of the coal synthine process. Most of the process water is needed for cooling and, for the figures used, it is assumed that cooling water would be recirculated through cooling towers.

Water for plants could be obtained directly from the Mississippi, Illinois, Ohio, or Wabash Rivers, with or without storage reservoirs depending upon the total quantity of water needed; from impoundments upon tributaries of these rivers in Illinois; from Lake Michigan; or from underground sources. A water supply development from Lake Michigan would be economical only in the event that water was required sufficient for a great many synthetic liquid fuels plants. Ground water sources appear to offer some promise of adequacy especially in and near the larger river bottoms, but the feasibility and cost of such development would have to be proved in each instance by test drilling and pumping, both of which are beyond the scope of this investigation. However, it appears reasonable to expect adequate ground water resources to meet requirements for domestic water supplies, especially in those areas where available surface waters are seriously polluted.

Sufficient water for at least one 10,000-barrel-per-day plant per General Area is available directly, without storage for stream regulation, from the Illinois River for five of the eight General Areas in central Illinois as well as for the remaining three, if the coal resources therein were developed to an extent beyond the capacity of local water supplies. The Ohio could serve the adjacent Saline General Area and also the Williamson General Area, with water withdrawn within the 45-mile stretch below the mouth of the Wabash River. The Wabash River could supply the Saline General Area and the Wayne General Area as well if diversion works were constructed below Mt. Carmel. Other General Areas would be more logically dependent upon local sources. Since each of the 31 General Areas of Illinois has sufficient coal and water to supply at least one synthetic liquid fuels unit plant for 40 years, they are all designated as General Areas of Coal and Water Availability.

Although there is sufficient water in the Ohio River basin to supply ultimate development, there are seven other States in the basin having coal reserves available for synthetic liquid fuels plants. Ultimate development of all the plants in the various states would create an excessive demand on the Ohio River. Although it is unlikely this condition will occur, the importance of the possible effect of large draughts upon low river flows demands consideration. Development of coal resources in adjacent counties in Indiana would require water from the Wabash River, and the importance of the possible effects of large draughts here would also require consideration.

Capital costs, as of March 31, 1950, to supply water for unit plants range from a minimum of $632,000 in the LaSalle-Grundy General Area to a maximum of $6,955,000 in the Macon General Area. These costs are based on an adequate water supply system for one plant in each General Area consisting of storage reservoirs (where necessary), pumping stations, power transmission lines, aqueducts, storage, and filtration at the processing plant sites.

Operating costs for water supplies (for process water) range from a minimum of $0.021 per barrel of products in the La Salle-Grundy General Area to a maximum of $0.088 in the Macon General Area.

Additional quantities of water required for full development could be obtained in the 31 General Areas by enlarging the water supply systems. Sufficient quantities of water could be obtained at from about one-half to slightly more than the unit cost indicated for a single unit plant, depending upon the amount of low-flow augmentation required by local and State authorities.

Suitability of General Areas

Power requirements for a hydrogenation unit plant amount to a total load of about 65,000 kw of which 40,000 kw can be supplied either from the outside or from a system integral with the plant proper. For the coal synthine process, waste heat can supply the steam necessary to generate the required power. In each of the 31 General Areas, local utilities would be willing and able to provide power, provided sufficient time were allowed for expansion of existing facilities. However, for plant operation, the most economical source of power for hydrogenation plants in any of the 31 General Areas would be steam generating stations built as an integral part of the plants, where power could be generated at an average cost of 6 mills per kilowatthour (100 percent load factor) without allowance for return on investment.

Construction and operation of synthetic liquid fuels plants will in general require direct rail or water connection and a highway connection. Railroad facilities are well distributed throughout the State of Illinois; all of the General Areas are readily accessible, with very easy grading, to common carrier railroad lines. Most of the General Areas are adjacent to improved highways, so that only connecting plant facilities would have to be constructed. Water transportation would be readily available to several of the General Areas.

Estimated capital costs for providing access transportation facilities are negligible in Clinton, St. Clair, and Randolph General Areas. Elsewhere, they range from a minimum of $3,500 in the Clay General Area to a maximum of $757,500 in the Southeastern Montgomery General Area. For both processes and in all General Areas, the cost of this item does not exceed one cent per barrel of products.

The average straight-time hourly rate, as of March 31, 1950, payable in a synthetic liquid fuels unit plant in Illinois is estimated at $1.72. There exists within a reasonable distance from an average unit plant in the coal counties of Illinois an ample supply of labor available to such a plant to meet its personnel requirements, both in total and in respect of skilled labor. Should a second unit plant be introduced within about 50 miles of the first plant it is possible that sufficient labor may not be available locally to staff such a plant and might necessitate increasing labor rates in order to attract workers from a distance.

The average net investment required for rental housing and community development in the average General Area, exclusive of one-half the residential property (assumed as sold) and exclusive of property used for commercial enterprises (assumed as self-supporting), is estimated as of March 31, 1950, at about $11,529,428 for a hydrogenation unit project and $13,375,079 for a coal synthine unit project. It is assumed that rental housing will pay for its operating and maintenance costs plus a required return on the investment.

For the purpose of analyzing potential markets, since neighboring states also have raw materials and water supply available for production of synthetic liquid fuels, the marketing territory for Illinois plants is defined as including the entire market in that State and in Wisconsin and Minnesota. In the marketing territory, motor fuel consumption in 1948 (exclusive of aviation and military use) amounted to 87.99 million barrels. This is equivalent to the gasoline output of 32 synthetic liquid fuels unit plants. It is estimated that by 1975 motor fuel requirements, on the same basis, will reach an annual volume of 142.24 million barrels, the equivalent of the output of 52 synthetic liquid fuels unit plants.

While the major product of hydrogenation and coal synthine plants is motor gasoline, minor quantities of other fuels are specified to be produced, including Diesel fuel, heavy fuel oil, and liquefied petroleum gases. The proportions of these fuels in relation to gasoline are considerably different from the present demand in the marketing territory. There is, however, some leeway in the processes, particularly the hydrogenation process, for varying the proportions of the various products. Consequently it would appear that any large-scale development in the future would require synthetic liquid fuels plants to be designed so as to produce the products then in demand.

In the marketing territory of Illinois plants, the demand for liquid fuels is met principally by local crude oil and the movement of crude oil and petroleum products from the west and southwest. Wholesale prices as of June 1, 1950, of petroleum products, fob. refineries in Illinois, amount to $4.314 per barrel when weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation plants and to $4.614 when weighted in the same pro-

portions as for coal synthine plants. The estimates of future demand for liquid fuels in the marketing territory may be substantially reduced by a major increase in liquid fuel prices, altering the basic competitive positions of fuels. The prospective future supply of petroleum appears adequate to satisfy at least the major proportion of future requirements for liquid fuels for a long period of years.

Synthetic liquid fuels plants situated in the 31 General Areas in Illinois would be well located for the distribution of their products within the marketing territory, whether the output of a single plant or a substantial number of plants were to be marketed. A single unit plant in any one of the General Areas, except possibly two in the southeastern part of the State, could market its output within a reasonable trucking distance of the plant. In the event of large-scale development, plants in certain General Areas could be connected by short pipe lines to the several products pipe line systems which already provide for a rather flexible movement of products and could utilize river and lake shipment by barge or tanker. Throughout the defined marketing territory, synthetic liquid fuels plants in Illinois would realize minimum costs of distribution.

The operation of synthetic liquid fuels plants, and of the coal mines to supply them with raw material, involves the production of wastes, for the disposal of which provision has been made. Liquid wastes may require skimming and sedimentation and in some cases chemical treatment before return to the streams; solid wastes (principally ash from the plant and refuse from coal cleaning) must be transported to the disposal areas and there piled up or compacted.

Comparison of Suitable General Areas

All of the foregoing economic features are reflected in the total capital costs and operating costs for synthetic liquid fuels plants in Illinois. Both cost estimates for the processing plant were based on the Bureau of Mines estimates of typical unit plant costs and were adjusted to existing conditions in the 31 General Areas.

Capital costs for initial hydrogenation unit projects, shown in Exhibit No. 67 as of March 31, 1950, range from a maximum of $125,607,000 in the Macon General Area to a minimum of $118,889,000 in the Peoria General Area. Similar capital costs for initial coal synthine unit projects, shown in Exhibit No. 68, range from a maximum of $119,689,000 in the Macon General Area to a minimum of $112,833,000 in the Peoria General Area. These estimates provide for adequate coal and water supply, plant facilities and access transportation, and include capital amounts for net housing investment. In addition there is provision for adequate plant waste disposal. Coal production costs include provision for cost of disposal of waste from mining operations and coal cleaning to provide a merchantable coal.

The estimated costs of synthetic liquid fuels in each General Area and the potential total plant capacities that could be supplied from the available recoverable coal reserves over a 40-year period of time in the 31 General Areas of Illinois are summarized, in order of relative desirability, for the two processes separately, in the following tables:

Order of Relative Desirability
of Suitable General Areas in Illinois
(As of March 31, 1950)

Suitable General Area	Type of Mining (A)	Potential Daily Plant Capacity (Thousands of Barrels)	Cost of Products in Initial Plants (Dollars per Barrel)
Hydrogenation Process:			
Peoria	S	10	$5.361
Perry	S	10	5.432
Northern Knox	S-U	10	5.458
Randolph	S-U	10	5.476
Perry (B)	S-U	10	5.566
Franklin	U	111	5.569
Saline	U	138	5.569
Northern Christian	U	137	5.620
Perry (C)	U	141	5.624
Macoupin	U	280	5.633
Williamson	U	71	5.649
Southeastern Montgomery	U	184	5.656
Randolph (C)	U	40	5.657
St. Clair	U	141	5.664
Jefferson	U	87	5.722
Logan	U	27	5.783
Menard	U	46	5.791
Sangamon	U	240	5.801
Macon	U	28	5.832
Washington	U	31	5.865
Madison	U	68	5.879
Bond	U	31	5.893
Peoria (B)	S-U	10	5.803
Jackson No. 5	U	50	6.002
Marion	U	22	6.094
Henry No. 6	S-U	10	6.140
Clinton	U	110	6.148
Vermilion	U	55	6.161
Peoria (C)	U	47	6.164
Fulton-Knox	U	38	6.248
Northern Knox (C)	U	6	6.304
Henry No. 6 (C)	U	21	6.343
Wayne	U	46	6.509
Marshall	U	10	6.520

Order of Relative Desirability
of Suitable General Areas in Illinois
(As of March 31, 1950)
(Concluded)

Suitable General Area	Type of Mining (A)	Potential Daily Plant Capacity (Thousands of Barrels)	Cost of Products in Initial Plants (Dollars per Barrel)
Hydrogenation Process:			
Clay	U	20	$6.523
Southeastern Grundy	U.	16	6.530
La Salle-Grundy	U	27	6.542
Bureau-Putnam	U	34	6.554
Total		2,373	

Note: (A) S-U: for strip and underground coal; U: underground coal only; S: strip coal only.
(B) Estimated additional plants using strip and underground coal when the initial plant in the Area had strip coal available.
(C) Additional plants using all underground coal when the first or second plants in the Area had available some strip coal.

Order of Relative Desirability
of Suitable General Areas in Illinois
(As of March 31, 1950)

Suitable General Area	Type of Mining (A)	Potential Daily Plant Capacity (Thousands of Barrels)	Cost of Products in Initial Plants (Dollars per Barrel)
Coal Synthine Process:			
Peoria	S	10	$5.401
Perry	S	10	5.485
Randolph	S-U	10	5.595
Franklin	U	87	5.655
Saline	U	107	5.663
Peoria (B)	S-U	10	6.305
Northern Christian	U	106	5.726
Perry (C)	U	115	5.733
Macoupin	U	218	5.742
Williamson	U	55	5.757
Northern Knox	S-U	10	5.758
Southeastern Montgomery	U	143	5.765
Randolph (C)	U	29	5.777
St. Clair	U	110	5.785
Jefferson	U	68	5.853

Order of Relative Desirability of Suitable General Areas in Illinois
(As of March 31, 1950)
(Concluded)

Suitable General Area	Type of Mining (A)	Potential Daily Plant Capacity (Thousands of Barrels)	Cost of Products in Initial Plants (Dollars per Barrel)
Coal Synthine Process:			
Logan	U	21	$5.938
Menard	U	35	5.945
Sangamon	U	187	5.959
Macon	U	21	5.989
Washington	U	24	6.042
Madison	U	53	6.063
Bond	U	24	6.078
Jackson No. 5	U	39	6.217
Marion	U	17	6.338
Clinton	U	86	6.409
Vermilion	U	43	6.419
Peoria (C)	U	31	6.434
Henry No. 6	S-U	10	6.448
Fulton-Knox	U	29	6.532
Northern Knox (C)	U	3	6.605
Henry No. 6 (C)	U	14	6.655
Wayne	U	36	6.870
Marshall	U	8	6.883
Clay	U	15	6.890
Southeastern Grundy	U	13	6.899
La Salle-Grundy	U	21	6.920
Bureau-Putnam	U	26	6.935
Total		1,844	

Note: (A) S-U: for strip and underground coal; U: underground coal only; S: strip coal only.
(B) Estimated additional plants using strip and underground coal when the initial plant in the Area had strip coal available.
(C) Additional plants using underground coal when the first or second plant in the Area had available some strip coal.

Operating costs for initial hydrogenation unit plants (excluding return on investment) range from a maximum of $6.554 per barrel of products (15.6 cents per gallon) in the Bureau-Putnam General Area to a minimum of $5.361 per barrel (12.8 cents per gallon) in the Peoria General Area. For coal synthine unit plants, similar figures range from a maximum of $6.935 per barrel (16.5 cents per gallon) to a minimum of $5.401 per barrel (12.9 cents per gallon) in the same General Areas.

Processing costs as stated herein, as directed by the Contracting Officer, are based on operating costs of the process rather than a "cost of service" or selling price basis. Such costs are based on the Bureau of Mines formula and include a basic allowance for plant maintenance of approximately 3 percent of plant investment. They also include an allowance equal to 10 percent of direct labor, plant maintenance, and operating supplies for general administrative and general office overhead (which includes the salaries and wages of a General Manager or a Plant Manager and his immediate staff reporting directly to management); 6-2/3 percent of plant investment for depreciation; and 1 percent of plant investment for insurance and local, county, and State real estate taxes; but they include no allowance for head office or top management costs, selling expenses, return on investment, or sales and corporate (including income) taxes. Costs of coal used in the process have been computed without including selling cost or return on the investment. The cost of water has been estimated on the same basis. Return on total initial capital investment, including coal and water as indicated herein, would require between 30.9 and 34.4 cents per barrel of products for each 1 percent gross return before the deduction of income taxes.

The costs herein are reported as per barrel of total products. Estimates of the equivalent cost of gasoline and credits for sale of by-products were not considered necessary for the determination of the most desirable General Areas. Because the product grades and quantities are different for each process, the raw material and process selected in each General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, comparison of General Areas has been made separately for each process.

From a strategic standpoint, it is believed that development of a synthetic liquid fuels industry could be planned in each of the 31 Suitable General Areas to conform with presently published policies of the National Security Resources Board.

PART I - INTRODUCTION

INTRODUCTION

Authorization

At the request of the Secretary of the Interior, the Department of the Army directed the Corps of Engineers to make a survey of the United States and Alaska to determine areas suitable for synthetic liquid fuels manufacture. In order to accomplish this survey, a contract (W 49-129 eng-137) was made between The United States of America and Ford, Bacon & Davis, Inc., (sometimes hereinafter referred to as the Contractor). This investigation and report have been made as a part of that required by the contract. By approval of the Corps of Engineers, Department of the Army, portions of the contract obligations were subcontracted to other firms engaged as experts in their particular fields of operation, as follows:

Subcontract No. 1 to Paul Weir Company, Inc., Chicago, Ill., for coal investigations.

Subcontract No. 2 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for natural gas investigations.

Subcontract No. 3 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for oil shale investigations.

Subcontract No. 4 to Malcolm Pirnie Engineers, (a partnership), New York City, for water supply investigations.

Subcontract No. 5 to Max W. Ball (an individual), Washington, D.C., for investigations of oil-impregnated strippable deposits.

Purpose

This study was undertaken to determine the potential synthetic liquid fuels production capacity of the State of Illinois. To make such a determination, three categories of study are usually required; in order, they are:

1. Investigate the reserves of coal, natural gas, oil shale, and oil-impregnated strippable deposits available for the manufacture of synthetic liquid fuels.

2. Select General Areas of Raw Material and Water Availability.

3. Determine the suitability of each General Area so selected for the production of synthetic liquid fuels.

Scope of Survey

In the selection of General Areas suitable for the location of synthetic liquid fuels plants, where all plant requirements can be met, the survey does not select or establish specific sites for the construction of a plant. The studies are based primarily on available information and data obtained from various authoritative sources. No detailed field surveys were carried out but a brief reconnaissance was made of a number of the General Areas.

Three of the subcontractors have made surveys and reported on raw materials in Illinois in accordance with their individual contracts. Their descriptions of conditions and their conclusions have been incorporated in appropriate sections of this report.

The raw materials considered in this survey are:

(a) Coal
(b) Natural gas
(c) Oil shale

Because of the known large deposits of coal in Illinois and their economic importance, a complete detailed survey of that raw material was authorized by the Corps of Engineers. This comprised, in addition to the determination of available coal reserves, a determination of water availability and a critical examination of the suitability of other conditions affecting plant location for the manufacture of synthetic liquid fuels.

As available information indicated that deposits of natural gas and oil shale do not exist in Illinois in sufficient quantities to constitute reserves as defined herein for the production of synthetic liquid fuels (although of possible economic importance), the Corps of Engineers directed that the investigation in respect to these materials be limited to a general determination of the nature and extent of such deposits and their suitability or unsuitability for the manufacture of synthetic liquid fuels. The scope of the required report, as well as the conclusions contained in this report, that available information indicated insufficient deposits of these materials to constitute reserves for the manufacture of synthetic liquid fuels, obviates the necessity for making an investigation in respect of these materials regarding General Areas suitable for the location of synthetic liquid fuels plants.

In accordance with the contract agreement, no consideration was given to the use of oil-impregnated strippable deposits since there are no known deposits of that raw material or only deposits of minor economic importance in Illinois.

To facilitate further study, those coal reserves found to be of satisfactory quality and quantity, were grouped into areas not larger than a county or 1,000 square miles. Where such areas contained reserves adequate for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, they were designated as General Areas of Coal Availability. Those Areas found also to have adequate supply of water for at least one 10,000-barrel-per-day plant were designated as General Areas of Coal and Water Availability.

General Areas of Coal and Water Availability were then critically examined with reference to following factors:

1. Raw materials
2. Water supply
3. Power
4. Access transportation
5. Labor
6. Housing
7. Marketing and products transportation
8. Waste disposal
9. Plant investment
10. Processing costs
11. Strategic considerations.

The total comparative costs per barrel of products determined from a study of the several factors listed above, together with consideration of other factors incapable of evaluation in dollars and cents, enabled the listing of the several Suitable General Areas in their order of desirability, considering separately each applicable manufacturing process.

PART II - GENERAL

GENERAL

The terminology used in this report is that in general use and acceptance. Such terms, together with those idiomatic to this survey, are defined in the following paragraphs:

Definition of General Terms

General terms used in this report are defined as follows:

A General Area as used herein is not larger than a county or 1,000 square miles, depending on local conditions. General Areas are used to facilitate the detailed study of parts of the State, and are designated by name or number.

A General Area of Coal Availability is one where adequate raw materials reserves are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material requirements for such plants.

A General Area of Coal and Water Availability is one where both adequate coal reserves and water supply are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material and water requirements.

A Suitable General Area is one which meets all requirements for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant using coal, in conformity with plant requirements as to raw materials, water supply, power, transportation, labor, housing, marketing and transportation of plant products, waste disposal, and strategic considerations.

A Unit Plant is the amount of production capacity adopted in the survey for purposes of comparison and for estimation of investment, operating costs, etc. It is not necessarily the most efficient size for an independent plant. The sizes adopted in the survey as unit plants are:

Sizes of Unit Plants

Process	Barrels Per Day
Hydrogenation of coal	10,000
Synthine process using coal	10,000

Definitions of Coal

Bituminous Coal - Coal having less than 86 percent fixed carbon (dry, mineral-matter-free basis) and, if fixed carbon is less than 69 percent, having a heating value of 11,000 or more Btu (moist, mineral-matter-free basis) and either agglomerating or nonweathering.

Types of Coal Mining and Related Terms

Strip Mining - The method of first removing the overburden so as to expose the coal seam, usually by power shovels or drag lines, and then "loading" the coal.

Underground Mining - The method of coal extraction through underground operations, usually by driving a tunnel or drift, or by sinking a slope or shaft.

Overburden - In strip operations, comprises the soil or surface material, or the geological formation overlying the coal seam.

Stripping Ratio - The ratio between the thickness of the overburden and the thickness of the underlying coal seam.

Overburden Ratio - The ratio between the cubic yards of overburden and the tons of recoverable coal.

Geological Terms

Geological terms in general use include the following:

Horizon (Geological) - Strata formed at the same time at different locations represent a geological horizon.

Stratigraphic Section - A vertical cross section showing the relative position and thickness of geological formations in a particular area.

Coal Bed or Seam - A well-marked or homogeneous division of a stratified series, characterized by a more or less well-defined divisional plane from its neighbors above and below.

Dip - The angle which the plane of a bed makes with the horizontal plane.

Outcrop - The occurrence of any geologic strata of rock or coal at the surface of the ground.

Parting -Extraneous material in a coal seam, in a relatively thin layer, separating parts of the seam. When parallel to the plane of the coal, partings usually consist of sedimentary material, such as clay, shale, or sandstone. Partings which cross the plane of the coal seam, commonly contain calcite, kaolinite, or pyrite.

Bone (or Bony Coal) - Slaty coal or carbonaceous shale found in coal seams.

Terms Relating to Classification and Analysis of Coal

Among the terms in general use relating to analysis, classification, and mining of coal are the following:

Raw Coal - Coal as it comes out of the mine, not having been subjected to cleaning or any other preparation.

Merchantable Coal - Processed or cleaned coal of a quality acceptable for commercial use, and generally equivalent (or in some cases superior) in analysis to that of a channel sample, i.e., secured from coal in place (see definition of Mine Sample, Face Sample, etc.).

Recoverable Coal - That portion of the total estimated coal in place that can be delivered as merchantable coal, after being mined and (where necessary) washed or otherwise cleaned, primarily to remove ash.

Proximate Analysis - An analysis made of coal for the determination of moisture, volatile matter, fixed carbon, and ash.

Ultimate Analysis - An analysis made of coal for the determination of constituent elements, as sulfur, hydrogen, carbon, nitrogen, oxygen (by difference), and ash.

As Received - The condition representing the sample as received at the laboratory, and for mine samples approximates closely the condition of the coal in the mine.

Moisture-free - A condition, actual or assumed, permitting the determination or calculation of the analysis of a coal sample excluding its moisture content.

Moisture- and ash-free (Maf) - An assumed condition permitting calculation of the analysis of a coal sample excluding its moisture content and its ash content.

Rank - The stage of coalification in the series as listed below in order of decreasing completeness:

Rank of Coal

Class	Group	Abbreviation
Bituminous	Low-volatile bituminous	Lvb
	Medium-volatile bituminous	Mvb
	High-volatile A bituminous	Hvab
	High-volatile B bituminous	Hvbb
	High-volatile C bituminous	Hvcb

Heating Value - Heat (gross) resulting from combustion of one pound of coal, expressed as Btu per pound with specification of sample condition, as "as received", "moist, mineral-matter-free", "moisture- and ash-free", or "dry".

Mine Samples, Face Samples, or Channel Samples - Samples secured from coal in place in the ground in accordance with procedures specified by the U.S. Bureau of Mines, which require that such samples be obtained by collecting material in a uniform channel extending from roof to floor of bed, except that partings of shale, bone, and pyrite 3/8 inch or thicker and lenses or concretions of pyrite or other impurities more than 2 inches in maximum diameter, or 1/2 inch in thickness, are excluded. Such analyses are representative of merchantable coals obtainable from a mine.

"Tipple" Samples - Samples collected in accordance with Bureau of Mines procedure, after the coal has received final treatment at the tipple or cleaning plant, or as it is loaded into railroad cars or trucks.

Delivered Samples - Samples taken in accordance with Bureau of Mines procedure, from coal delivered for use as unloaded from the railroad cars or trucks.

Inorganic Sulfur - That portion of the total sulfur content (in coal) which exists in the form of sulfides and sulfates, the former commonly being iron pyrites, marcasite, chalcopyrite, arsenopyrite, and stibnite, with calcium sulfate (gypsum) the more usual sulfate.

Organic Sulfur - That portion of the total sulfur content other than the mineral sulfides and sulfates, which is combined in organic compounds.

Hydrogenation Yield - The relative quantity of liquid hydrocarbon products obtained by hydrogenation of a unit quantity of a particular coal.

Washability of Coal - The extent to which extraneous objectionable impurities (such as mineral matter, bone, and/or inorganic sulfur) can be reduced by treatment in commercial coal cleaning plants, with due consideration to the loss of coal which accompanies such treatment and the size limits of the coal before and after treatment.

Survey Specifications as to Minimum Requirements for Coal

The minimum requirements for bituminous coal deposits considered in this survey are as follows:

1. Thickness -

   A. For coal to be mined by underground methods - At least 24 inches.

   B. For strip-mined coal - Minimum thickness 12 inches.

2. Depth

   A. Underground-mined Coal - Not more than 1,500 feet below drainage level.

   B. Strip-mined Coal - Not more than 200 feet of overburden.
      (1) Stripping Ratio (for coal mined by stripping) - Not more than 40 to 1 up to 75 feet of overburden, and 8 to 1 for overburden in excess of 75 feet.

   The classification of coal deposits as "Strippable" shall be governed by the experience and good judgment of the coal subcontractor as to the economy of that operation.

3. Minimum Recoverable Tonnage (in an area of 3 miles radius) - 30,000,000 tons for underground mining or 5,000,000 tons for stripping.

Survey Classification of Coal Reserves

Coal reserves have been classified into three groups, and the tonnages of each have been computed, on the basis of the following definitions:

Measured Coal - Coal for which tonnage is computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes, with the points of observation, in general, on the order of 1/2 mile apart.

Indicated Coal - Coal for which tonnage is computed partly from specific measurements, and partly from projection of visible data for a reasonable distance on geologic evidence; the points of observation, in general, are of the order of 1 mile apart but may be as much as 1-1/2 miles for beds of known geologic continuity.

Inferred Coal - Coal for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, and for which there are few, if any, measurements. The estimates are based on an assumed continuity, for which there is geologic evidence. Where there are only outcrop data on which

to base estimates, such inferred coal is that lying more than 2 miles in from the outcrop and within limited areas (established as described by Paul Averitt, of the U.S. Geological Survey in a paper published in the magazine "Mining Engineering" of June 1949).

Classification of Coal Reserves in Respect of Plant Requirements

Available Coal Reserves - The amount of estimated recoverable coal remaining after deduction of estimated commercial and industrial requirements. Available coal reserves include Primary and Secondary Reserves.

The classification of bituminous coal reserves as primary and secondary is based upon thickness of seam and class of reserve as measured, indicated, or inferred. Thus, primary reserves for underground mining include only beds 28 inches or more in thickness which are classed as either measured or indicated. The complete classification is as follows:

1. Primary Reserves ("Measured" and "Indicated" only)
   a. Underground - At least 28 inches in thickness.
   b. Strip - Minimum thickness of 12 inches. Not more than an average depth of 75 feet of overburden; stripping ratio not to exceed 15 to 1.
2. Secondary Reserves ("Measured", "Indicated", and "Inferred" not included in Primary Reserves)
   a. Underground - At least 24 inches in thickness.
   b. Strip - Minimum thickness of 12 inches. Not more than an average depth of 200 feet of overburden; stripping ratio not to exceed 40 to 1 up to 75 feet of overburden and 8 to 1 for overburden in excess of 75 feet.

Terms Relating to Water Supply

Surface Water - Water in a natural open channel or a natural lake.

Ground Water - Water existing below the surface of the ground in a porous material. It may be either stationary or moving.

Firm Water - A quantity of water that is available for use at all times - year in and year out.

Acre-Foot (AF) - A quantity of water necessary to cover an area of one acre with water one foot deep.

Collection of Data

In the course of the investigation, all available data pertaining to Illinois were obtained from various sources, especially the U.S. Geological Survey, U.S. Bureau of Mines, and various Illinois State agencies. Certain information of value was secured from railroad companies serving the coal-bearing portion of Illinois, from local chambers of commerce, and from individuals.

A brief reconnaissance was made of nearly all of the areas selected as General Areas of Coal and Water Availability.

PROCESSES AND PLANT REQUIREMENTS

Processes Considered for Illinois

The term "synthetic liquid fuels" as used in this report is applied to liquid fuels made by hydrogenation or coal synthine processes using bituminous coal as a raw material.

Unit Plant

As a basis for estimates for purposes of comparison in this survey, a unit plant (unit of plant capacity or unit capacity) has been adopted which is not necessarily the most efficient size for an independent plant. The production capacity to be understood for both the coal hydrogenation and coal synthine processes, when the term "unit plant" is used, is 10,000 barrels per calendar day.

Basis of Estimates

The prime purpose of the estimates of construction and manufacturing cost presented in this report is for use in determining the relative desirability of individual areas as potential locations for synthetic liquid fuels plants. Since it is probable that some years would be required to construct any significant number of plants of this magnitude, it was decided for comparative purposes to base estimates of plant requirements and plant and product costs upon the assumed use of certain improvements in process (including the direct pressure gasification of coal) which are still under development here or abroad but which appear reasonably likely to be applicable by the time any synthetic liquid fuels program could be well under way. If synthetic liquid fuels plants were constructed today, basic requirements and costs might be appreciably higher than the estimates given, due to the necessity for the use of equipment and processes now commercially available. In drawing other than relative conclusions from these estimates, therefore, this qualification must be clearly recognized.

Detailed data as to plant requirements, products and plant wastes, for typical plants operating on both the hydrogenation and synthine processes, as furnished for use in this report, are shown in Exhibit No. 71.

Hydrogenation Process

History. Hydrogenation of coal to yield synthetic liquid fuels was the original concept of Franz Bergius, for which German Patent No. 301,231 was granted in 1913. The process, after intensive development and modification, was used to produce about 85 percent of German aviation gasoline in World War II. Germany then had

available a total daily nominal liquid fuels producing capacity of about 90,000 barrels in 12 plants.

In the United States, hydrogenation of coal has been studied intensively by the Bureau of Mines at Bruceton, Pa., and at Louisiana, Mo. At the latter location a coal hydrogenation plant has been erected and operated experimentally and for demonstration purposes with a daily capacity of about 200 barrels per stream day. Commercially, hydrogenation has been limited in the United States to the occasional upgrading of various petroleum fractions in four or five separate commercial units.

Nature of Process. The conversion of coal into liquid fuels by hydrogenation consists of combining hydrogen with the coal substance at elevated temperatures (about 700 to 900 deg F) and pressures (ranging from 3,000 to 10,000 psi) in the presence of catalysts. The process is extremely flexible with respect to the nature and proportions of products. As an example, by varying plant equipment, operating conditions, nature of catalyst, and/or plant design, gasoline output may be varied from less than 20 to over 90 percent, or fuel oils from zero to about 80 percent. The gasoline contains a high proportion of aromatics (benzene, toluene, and xylene) which may be separated if required, making the hydrogenation process an important potential source of these products. A considerable amount of phenols is also available as a by-product.

In condensed summary, the hydrogenation of coal consists in preparation of the raw material by careful washing, drying, and grinding, and formation of a paste by mixing part of the heavy oils from the first stage of hydrogenation with the prepared coal and a suitable solid catalyst. This paste, under high temperature and pressure, reacts with hydrogen in the first or liquid phase hydrogenation. Phenols may be separated from the products at this point or may be carried on with the rest of the products to the second or vapor phase hydrogenation. This phase consists in passing a gaseous mixture of hydrogen and the vaporized products from the first stage through beds of appropriate granular solid catalysts. The output of the second stage of hydrogenation is separated into the various final products, mainly by distillation employing equipment and methods not varying greatly from those commonly used in the petroleum industry.

Hydrogen for the first stage (liquid phase) and second stage (vapor phase) hydrogenation is obtained in part from water gas produced by reaction between steam, oxygen, and coal and in part by cracking with steam the light hydrocarbon gases which are by-products of the main hydrogenation. Provision is also made for recovery and reuse of the portion of hydrogen not consumed in the reaction vessels. Pressure operation of coal gasification and hydrocarbon cracking equipment is assumed.

Cooling water is injected into the hot gas streams leaving the hydrogenation converters. This water, together with additional water formed in the reaction, condenses out and is separated from the product oil streams before distillation, carrying with it some dissolved hydrogen sulfide and phenols and constituting the major contaminated liquid process waste.

The appended block flow diagram, Exhibit No. 1, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design for which estimated construction and operating costs are given in this report. It should be remembered, however, that the principle of coal hydrogenation is extremely flexible in application and that variations in methods of hydrogen production, ash elimination, product processing, and number and balance of hydrogenation steps may be used in individual plants designed to meet different local conditions.

Plant Requirements. The principal materials required for the hydrogenation process are coal and water. Other materials include catalysts used in hydrogenation and hydrogen production and chemicals used in gas scrubbing. Remaining other materials are relatively insignificant in both value and volume.

Coal. Coal is used in the hydrogenation process for conversion to liquid fuels, for the manufacture of hydrogen and fuel gas, and as fuel, both for steam power generation and in certain direct-fired operations. That portion of the coal to be hydrogenated to liquid fuels should be of good quality; the balance may be of inferior grade. Roughly one-half of the total coal used in the plant is converted into liquid fuels, the other half being consumed to supply energy and hydrogen for the process. A unit plant of 10,000 barrels daily capacity would require daily about 4,400 tons of Illinois coal, dependent on the heating value.

Coal readily washed to low-ash content is preferable to less easily washed coals of the same type.

Coal is a complex and variable material. Actual trial of an adequate sample in a pilot plant is the only sure criterion of the practicality and ease of hydrogenation. The following properties of coal are, however, indicative of its amenability to the process:

1. The following factors should be high -

   (a) Net hydrogen content
   Hydrogen in excess of that theoretically required to combine with all oxygen, nitrogen, and sulfur of the coal.

   (b) Volatile matter
   Not less than 31 percent (maf).

   (c) Tar and bitumen yields on carbonization.

   (d) Iron and chlorine
   Of the inorganic constituents of coal, iron and chlorine usually affect the catalysts favorably.

2. The following factors should be low -

   (a) Fixed carbon content
   Not over 69 percent (maf).

   (b) Oxygen
   Oxygen of the coal appears in part in the form of phenols, the balance combining with hydrogen to form water and with carbon to form oxides. Phenols may be converted in the second stage hydrogenation to hydrocarbons and additional water.

   (c) Ash
   Low-ash content is desirable as reducing both the total amount of coal to be handled, and loss of oil (carried out of the system with rejected ash). Ash content should be minimized by washing. Fusion point of the ash is not of major importance. Maximum permissible ash content (dry basis) is 15 percent for process coal and 20 percent for other uses.

   (d) Calcium and alkali
   These constituents may cause operating difficulties by their effect on the catalysts.

   (e) Fusain and opaque attritus
   These constituents of coal (determined by petrographic analysis) are difficult to convert but may be in part hydrogenated to liquid fuels. Fusain is normally largely removable by proper preparation.

   (f) Nitrogen
   Largely converted to ammonia by hydrogenation.

(g) Sulfur

Largely converted to hydrogen sulfide and other sulfur compounds.

Water. The hydrogenation of coal and the production of the energy required by the process develop large amounts of heat which must be removed. The availability of an adequate supply of cooling water is therefore of great importance. Although more than 120 mgd must pass through a unit plant with a 33 deg. F rise in temperature, the total water requirements can be reduced to 7.3 mgd by recirculation through cooling towers. Two-thirds of the make-up water is lost by evaporation when recirculation is used. The balance is returned to the source as wastes from coal separation, as blowdown from cooling towers and boilers, and as sewage.

Power. The hydrogenation of coal requires installed generating capacity to supply 68,000 kw at 100 percent load factor for the operation of a unit plant which includes an allowance of 3,000 kw for mine operation. Of the total, approximately 25,000 kw can be supplied in connection with the production of process steam. Purchase of the excess prime power requirements of about 40,000 kw from outside sources could decrease the total coal requirement of the process by approximately 12 percent, water requirement by about 17 percent, and would also effect reductions in manpower requirements and in investment in power generating facilities. However, the magnitude of the installation required for handling process coal alone, together with the desirability of an outlet for the higher ash fractions of the washed coal, would usually make purchase of outside power disadvantageous. Outside power sources are desirable as stand-by capacity. The possible mutual advantage of integrating the electric generation of the plant into an existing power network should be considered.

Personnel. Plant operating personnel must be high grade, semitechnical labor as in the chemical and petroleum refining industries. Highly qualified machinists and mechanics are required for the effective and safe maintenance of high-pressure equipment. Indirect labor includes such classifications as material handlers, stock clerks, guards, watchmen, and janitors. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the manpower required for a hydrogenation plant can be trained in the plant, and would require no specialized skill prior to employment.

The number of employes of a unit plant, including labor and supervision, will vary slightly according to the proportion of the total output represented by the various final products, but may be stated for a typical example in continental United States as follows:

Personnel Required for
a Typical Hydrogenation Unit Plant
in Continental United States

Classification	Number of Personnel		
	Operational	Administrative	Total
Operations:			
Labor	365	-	365
Supervision	37	-	37
Maintenance:			
Labor	430	-	430
Supervision	43	-	43
Indirect Labor	50	53	103
Indirect Salaried Personnel	-	197	197
Total	925	250	1,175

Plant Products and By-products. The hydrogenation process can produce, from coal as raw material, liquid fuels covering the entire range from heavy fuel oil, through Diesel fuel, jet fuel, and motor gasoline, to 100-octane aviation gasoline. By varying operating conditions, number of hydrogenation steps, and choice of catalyst any one of these grades may be made the principal product, as local markets may require.

The gasoline produced by hydrogenation of coal contains a high proportion of aromatics (benzene, toluene, and xylene), which may be separated if required, making the hydrogenation process an important potential source of those products.

Liquefiable petroleum gases (propane and butane) form an appreciable percentage of total plant products. A considerable amount of phenolic compounds, including phenol, cresol, and xylenols, may also be separated as optional by-products. If left in the main product stream, they are ultimately converted to additional gasoline.

Wastes. The hydrogenation of coal produces gaseous, solid, and liquid wastes. Gaseous wastes result in part from the combustion of coal in the power plant and at other points. Sulfur in the coal fed to the hydrogenation converters is separated from the process stream as hydrogen sulfide. This may be converted to sulfuric acid or elemental sulfur and sold, or burned in the power plant and dissipated from the stack with the other flue gases, according to local conditions. Small amounts of ammonia which might be discharged could be rendered inoffensive by passage through a combustion zone.

Solid wastes of the process are comparable to and would be disposed of in the same manner as solid wastes from any large coal-burning industrial plant. Although coal hydrogenation ash will contain about eight pounds of spent catalyst per barrel of plant products, its volume and nature will present no disposal problems not adequately met by usual methods employed to prevent the carrying off of excessive suspended solids by rainfall.

Various liquid wastes of the hydrogenation plant may carry small amounts of oil, removable by separators such as are commonly used by petroleum refineries. Of the total amount of liquids to be discharged, a relatively small and segregable portion will consist of so-called "foul water" containing dissolved gases (such as hydrogen sulfide) and solids, principally phenolic in nature.

A variety of methods is available for removing phenolic compounds. They may be applied in a series of consecutive steps, the number of steps depending on the degree of purification required by local conditions. These would be arranged in the following order.

1. Preliminary removal of remaining oil by solvent extraction followed by removal of the bulk of the dissolved gases by pressure release and heating or aeration.

2. Removal and recovery of phenols by ion exchange on highly alkaline exchange resins; or, alternatively, destruction of phenols by biochemical action.

3. Oxidation of remaining traces of phenols by ozone.

A more detailed discussion will be found in the section on waste disposal, in a later part of this report.

Choices between methods will be largely determined by economic factors at specific locations. Treated water can be rendered suitable for return to streams without harm to aquatic life and may be rendered potable by standard treatments.

Typical Hydrogenation Plant for Continental United States. In selecting a form of coal hydrogenation plant suited to the conditions imposed in the continental United States by the types of coal available and the required types and proportions of products, the Bureau of Mines has prepared estimates in its publication, R.I. 4564 (August 1949), for several typical plants, each of 30,000-barrel-per-day capacity. These data for a plant to use Wyoming bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant. More generalized data may be summarized as follows for a typical unit plant.

Basic Data and Estimates
for Typical Unit Coal Hydrogenation Plant
in Continental United States
(Based on U.S. Bureau of Mines Data)

Plant area - Acres (minimum)	70
Estimated approximate total steel requirements - Tons	60,000
Estimated Personnel:	
Operations and maintenance	925
Administrative, clerical, and engineering	250
Total daily coal requirements - Billions of Btu	98
Power required at 100 percent load factor - Kw	65,000
Daily water requirement - Gallons	7,286,000
Total production - Barrels per calendar day:	
Gasoline	7,220
Liquefied petroleum gas (L.P.G.)	2,367
Phenols	413(A)

Note: (A) Convertible, without additional equipment, to 463 barrels additional gasoline.

The current stage of development of a synthetic liquid fuels program does not permit the statement that any specific plant represents average conditions for those which may be constructed. Variations from the mean, however, will not seriously affect the utility of such a plant as a basis for the purpose of this survey, i.e., the determination of the relative suitability of General Areas.

Synthine Process Using Coal

History. Early work in Germany by F. Fischer and H.Tropsch developed a process to combine carbon monoxide and hydrogen, producing a mixture of alcohols which was called synthol. In 1926, the same men announced a modification of their process to produce, from the same gases, a mixture of hydrocarbons. To indicate the close similarity, this product was termed synthine and has given its name to the process itself.

Intensive development after 1926 resulted in the construction of a commercial plant in 1936 by Ruhrchemie, A.C. Following this installation, the number of synthine plants in Germany increased to a total of ten by the end of World War II. Required carbon monoxide and hydrogen were produced by conventional water gas equipment.

Development of the process by others has been followed for many years by the U. S. Bureau of Mines, which since 1945 has itself carried on active work at Bruceton, Pa. Simultaneously, research on the continuous production of synthesis gas (a carefully proportioned mixture of carbon monoxide and hydrogen) has been under way at Morgantown, W. Va. A 50-to-100-barrel-per-day demonstration plant for the Bureau of Mines is nearing completion at Louisiana, Mo.

Private capital has nearly completed a 7,000-barrel-per-day synthine plant to use natural gas near Brownsville, Tex.

Nature of Process. Except for obvious necessary differences in the production of synthesis gas, and in disposal of waste products, the synthine process is the same whether coal or natural gas is used as the primary raw material.

The synthine process consists essentially of the combination, over a suitable catalyst at pressures of from 200 to 400 psi and at temperatures of from 550 deg to 650 deg F, of carbon monoxide and hydrogen to form a condensable mixture of hydrocarbon vapors. The reaction releases large amounts of heat and, since the temperature may be allowed to vary only within narrow limits, adequate provision for cooling is important. The liquid products are recovered and, for the most part, separated by methods and equipment well known in petroleum technology. Subsequent catalytic cracking or hydrogenation of the heavier oil fractions may be used according to the desired product distribution.

In the reaction, most of the oxygen of the carbon monoxide is converted to water but a part reacts to form carbon dioxide and a series of both water- and oil-soluble oxygenated organic compounds consisting of alcohols, aldehydes, ketones, and acids.

The nature and quality of products of the synthine process depend entirely upon the type of catalyst used and the operating conditions regardless of the raw material used to produce the synthesis gas. This gas can be produced from any material containing combustible carbon, the hydrogen being obtainable by reaction of steam and carbon monoxide.

The principal raw materials suitable for the synthine process are coal of all ranks and natural gas. Of these, the former is available in much larger quantities. Although the latter is commonly less expensive, it is also usually less available when existing commercial demands are satisfied.

The appended block flow diagram, Exhibit No. 2, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design, for which estimated construction and operating costs are given in this report. However, the synthine process is more or less flexible in application, and variations in method of synthesis gas production, type of synthesis reactors, number of reaction stages, steps in product pro-

cessing and manner of separation or reuse of oxygenated chemical by-products may be used in individual plants designed to meet different local conditions.

Plant Requirements. The synthine process uses major quantities of coal and of water. Other necessary materials, including chemicals for catalyst manufacture, for the treatment of intermediate liquid products, and for imparting anti-knock properties to finished gasoline, are of relatively small amount.

Coal. Coal for the synthine process may be of any rank and of almost any quality although low quality (heating value) will obviously increase the quantity required for a given plant capacity. A unit plant of 10,000 barrels daily capacity would require daily about 5,700 tons of Illinois coal, the exact amount dependent upon the heating value. Ash content is not inherently objectionable but should preferably be as low as possible. To this end, good washability is desirable. The maximum permissible ash content is 20 percent (dry basis). High sulfur content in the coal is to be avoided because of the necessity for nearly complete sulfur removal from the synthesis gas, in order to maintain catalyst activity.

Water. Water is required in a synthine plant mainly for cooling purposes. Too high a solids content will somewhat increase requirements for solids control in cooling towers and boilers. From one-eighth to one-fourth of the water used must be capable of treatment to provide satisfactory boiler feed. Less than 1 percent need be of potable quality or fit to be made so by chlorination and other treatment. For a unit plant, the total daily requirement is about 11,150,000 gallons per day.

Power. The basic chemical reactions of the synthine process liberate quantities of waste heat sufficient for the generation of all required electric power and no additional fuel for power would be required. Outside power is required for starting up and in the event of temporary failure of plant generating facilities. Integration where possible of plant facilities with an existing power net-work merits consideration.

Personnel. Operating personnel for a synthine process plant must be largely of a high class of semitechnical labor as in the petroleum refining and chemical industries. Because of the use of pressure equipment, the same is true of a substantial proportion of maintenance labor. Roughly, 20 percent of the total manpower may be common labor. Indirect personnel includes such classifications as material handlers, stock clerks, guards, watchmen, janitors, and laborers. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the technical workers can be trained from an inexperienced local labor supply.

The number of employes of a unit plant will vary slightly according to the proportions of the total output represented by the various final products, but may be stated for a typical example as follows:

Personnel Required for
a Typical Unit Coal Synthine Process Plant
in Continental United States

Classification	Number of Personnel
Operations:	
Wage Earners	338
Supervision	34
Maintenance:	
Wage Earners	420
Supervision	42
Indirect Labor (Wage Earners)	103
Indirect Salaried Personnel	198
Total	1,135

Plant Products and By-products. The synthine process can produce a series of hydrocarbon liquid products comparable to petroleum fractions and meeting similar commercial specifications. Although it is expected that normally a preponderant part of the output will be gasoline, a certain limited flexibility is possible in design and operation through variations in the catalyst used and in operating conditions.

Gasoline quality from a synthine plant varies widely with the type of catalyst used. The German practice of using cobalt produced gasoline of markedly low octane number. Use of iron catalysts and higher operating pressures as contemplated by the Bureau of Mines are expected to result in entirely satisfactory motor gasolines.

Diesel oil by the synthine process is expected to be of good quality with a cetane number of about 55. The typical fuel oil product is expected to meet specifications for a higher grade than No. 6 (Bunker C), possibly as high as No. 3.

A small amount of liquefiable petroleum gases (L.P.G.), principally propane, may be produced as final product (as assumed in the basic data for a typical coal synthine plant, see table following) or may be recycled or burned as plant fuel. The same is true with respect to a series of oxygenated organic compounds formed by part of the oxygen content of the synthesis gas. Most of these products, alcohols, aldehydes, and acids, have a definite

though limited market which probably could not absorb the output of such chemicals from any large production capacity of synthetic liquid fuels by the synthine process. Recycling of any of these materials is entirely possible and would result not only in solving a disposal problem but also in somewhat increased liquid fuel output or alternatively decreased raw material consumption. This practice is assumed in the specific plant design for which cost estimates are given in this report.

Wastes. Solid wastes of a typical synthine plant processing coal will consist principally of ash from the coal processed or burned as fuel. The small amounts of spent catalyst (mainly iron oxide) included will be no more obnoxious than the ash. Disposal of this waste offers no problem, except perhaps in quantity, that is not readily met in the case of any large coal-burning industrial plant.

Gaseous wastes will be principally those removed in the purification of the synthesis gas, especially hydrogen sulfide resulting from sulfur in the coal. In order to avoid atmospheric pollution, the hydrogen sulfide may be converted to sulfuric acid or elemental sulfur, the sale of which would provide a credit against cost of sulfur removal.

Liquid wastes of the plant can be handled so as to skim those carrying oils and to segregate those containing dissolved organic compounds from the process. Such segregated water, before discharge, may be treated for recovery of these compounds, either for sale or for recycling. Alternatively, it may be fed to special boilers to produce a contaminated steam replacing part of the normal process requirement. Relatively small quantities of sanitary and storm sewage can be handled by well-known methods. Some water from cooling tower operation and boiler blowdown will be discharged with an increased content of dissolved solids.

Typical Synthine Plant (Using Coal) for Continental United States. Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the United States and in Germany, the Bureau of Mines has in the course of preparation estimates of construction and operating costs of a synthine plant of commercial scale. Preliminary data from this study, for a plant producing 10,000-barrels of synthetic liquid fuels per day from western Kentucky bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant, to be used as a basis of comparison for determining relative suitability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

More generalized data may be summarized as follows for a typical unit plant:

Basic Data and Estimates
for Typical Coal Synthine Unit Plant
in Continental United States
(Based on Preliminary Data from U.S. Bureau of Mines)

Plant Area - Acres (minimum)	77
Estimated Personnel:	
Operations and maintenance (including all indirect labor)	937
Administrative, clerical and engineering (salaried personnel only)	198
Total daily coal requirements - Billions of Btu	126
Power required at 100% load factor - Kw (produced from waste heat)	114,500
Daily water requirements - Gallons	11,150,000
Total production - Barrels per calendar day:	
Propane	470
Gasoline	7,280
Diesel oil	1,900
Fuel oil	350

The current stage of development of the synthetic liquid fuels program does not permit the statement that any specific plant represents average conditions for those which may be constructed. Variations from the mean, however, will not seriously affect the utility of such a plant as a basis for the purpose of the survey; i.e., the determination of the relative suitability of General Areas.

PART III - SUMMARY OF STATE CHARACTERISTICS

SUMMARY OF STATE CHARACTERISTICS

Surface Features

The surface of Illinois consists of a level or slightly undulating plain, averaging 550 feet in elevation. The surface rises to ranges of low hills in the northwestern and southern sectors and there are occasional bluffs along the Illinois and Mississippi Rivers. The water courses flow generally from the north and northeast to the south and southwest.

A rich, black loam or mold, underlain by deep drift deposits, forms the soil with alluvial material common in the river valleys. The soil in most parts of the State is quite fertile.

Climate

Exhibit No. 3 shows average precipitation and temperature from the records of a weather station (Springfield, Sangamon County,) centrally located in the coal-producing counties. The maximum normal temperature, 77 degrees, occurs in July, the minimum, 27 degrees, in January. Rainfall approximates 36 inches per year. Mean snowfall is 12 inches in the south and 40 inches in the northern part of the State.

Population

The 1940 U. S. Census indicated that Illinois had a population of 7,897,241. The population had increased to 8,684,513 according to the 1950 census. Using the latter figure, the population density was 155 persons per square mile over the Illinois land area of 55,947 square miles.

In the area of the State containing raw materials suitable for synthetic liquid fuels manufacture, the population total was 1,769,333 according to the 1950 census. This area contains the 35 major coal-producing counties which have a total area of 21,227 square miles, resulting in a population density of 83 persons per square mile.

Industry and Agriculture

The major industries of Illinois include machinery, food and kindred products, fabricated metal products, and the primary metal industries. The 1947 Census of Manufacturers reported a total of 15,988 establishments with 2,511 establishments in the printing and publishing industries. Illinois is also among the bituminous coal-producing states and a major center of petroleum refining. Agriculture also plays an important part in the State's

economy with approximately 10 percent of the total labor force engaged in farm work.

The table which follows shows the size of manufacturing establishments in Illinois as compared to the United States total. These figures for establishments are from the 1947 Census of Manufactures and indicate that in Illinois there are proportionately fewer small manufacturing establishments and more large establishments than the United States average. Population figures are from the 1950 census.

Manufacturing Establishments in Illinois
and the United States Total
By Size Groups

Employes per Establishment	Illinois		United States		Illinois Percent of U. S.
	Number of Establishments	Percent of Total	Number of Establishments	Percent of Total	
1-19	9,593	60.0%	157,651	65.4%	
20-99	4,308	27.0	58,688	24.4	
100-499	1,669	10.4	19,878	8.3	
Over 500	418	2.6	4,664	1.9	
Total	15,988	100.0%	240,881	100.0%	6.64%
Population	8,684,513		150,697,361		5.76%

Transportation

An excellent transportation network is available in Illinois. Sixty-eight railroads are operatingin the State, with a total trackage in excess of 12,000 miles. Freighter service is available at the lake ports and barge lines operate on many of the rivers, including the Mississippi, Illinois, and Ohio. Water transportation is facilitated by canal connections between Lake Michigan and the Illinois and Mississippi Rivers to points south. There is also a more northerly connection between the Illinois and Mississippi Rivers.

Other Features

The economy of Illinois is influenced to a great extent by the proximity of Chicago and, to a lesser extent, by St. Louis. These two cities are centers of population, industry, transportation, and distribution, and the economy of the State is geared to their industrial activity.

PART IV - RAW MATERIALS

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GEOLOGICAL SURVEY
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COAL

General Geology of Coal Deposits

Coal-bearing formations of Pennsylvanian age solidly underlie approximately the southern three-quarters of Illinois, except for narrow marginal areas along the Mississippi, Ohio, and lower Illinois Rivers. These narrow areas and the northern one-quarter of the State are underlain by surface bedrock formations geologically older than the Pennsylvanian. These older formations are not known to contain workable coal deposits and the areas immediately underlain by such bedrock strata are not considered further in this report. Footnote references included in this section refer to publications listed in the bibliography, Exhibit No. 4.

The Pennsylvanian coal-bearing system occupies an area of approximately 36,800 square miles and includes all or portions of 84 counties. This area forms a portion of the coal basin extending through Indiana and western Kentucky, which is designated as the Eastern Region of the Interior Province by the U. S.

The Pennsylvanian period of geologic time is commonly divided in Illinois into the basal Pottsville, the intermediate Carbondale, and the upper McLeansboro formations. These formations correspond roughly with the Pottsville, Allegheny, and Conemaugh formations of the Pennsylvanian period in the State of Pennsylvania.

The coal measures of Illinois occupy a spoon-shaped, structural basin, broad across the northern end of the coal-bearing area and narrowing toward the south. This basin contains a relatively deep trough, which extends slightly east of south from near the middle of the north boundary of the basin to Wayne and White Counties on the south. This deeper trough within the Illinois basin is bounded on the northeast by the LaSalle anticline, which extends in a northwest-southeast direction from southwestern LaSalle County to southeastern Lawrence County. The trough is bounded on the southwest by the Duquoin anticline, which extends in a general northward direction across eastern Perry and Washington Counties. Both of these anticlines are unsymmetric in form to the extent that one limb of each fold is inclined more steeply than the other. Between these opposing monoclines lies the deepest part of the basin, in which are situated the most important recently developed oil fields of Illinois.

In accordance with this regional structure, the coal beds of western, northern, and eastern Illinois dip gently toward the central axis of the basin, steepening in dip as they cross the anticlines, and flattening out at depth as they approach the central

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(References: 6, 7, 11, 13, 14, 23, 24, 28, 29, 32, 33)

axis of the deep trough between the anticlines. From Wayne and northeastern Jefferson Counties the coal-bearing strata rise gently but with accelerating gradient toward the southern margin of the coal measures, which lies along a pronounced belt of uplift that crosses Union, Johnson, Pope, and Hardin Counties from west to east. This uplift is geologically and physiographically an eastward extension of the Ozark uplift of southern Missouri. The southern belt of pronounced uplift, including portions of the coal measures in southern Franklin, Williamson, Saline, and Gallatin Counties, is characterized by a zone of irregular faulting and folding. Vertical dikes of basic igneous rock were intruded into and through the coal beds of Saline County during post-Pennsylvanian diastrophism.

The Pennsylvanian strata thicken gradually toward the southeastern part of the State where they attain a total thickness of approximately 2,000 feet. At least 16 coal beds have been identified within this vertical thickness, of which five beds have been mined over relatively large areas while the remaining have been mined only in local areas of limited thickening. Because of the regional dip of the beds toward the trough of the Illinois basin, the coal beds are minable by strip or drift openings only in the areas of outcrop around the northern, western, and southern margins of the coal-bearing area. A large proportion of the mining in the principal coal beds is carried on through slope or shaft openings below drainage level, at depths which have exceeded 1,000 feet but which generally range from less than 100 to approximately 600 feet. The principal coal beds and coal horizon markers, in descending order, are shown by the following section:

Principal Coal Beds and Coal Horizon Markers in Descending Order

Formation	Coal Bed
McLeansboro	Coal No. 8
	Coal No. 7
Carbondale	Coal No. 6
	Coal No. 5
	Coal No. 2
Pottsville (Tradewater Group)	Dekoven
	Davis
	Coal No. 1
	Murphysboro
	Willis
Pottsville (Caseyville Group)	Battery Rock

The above section does not include some coal beds in the upper part of the McLeansboro formation, which outcrop in the central and southeastern portions of Illinois and on which correlations are uncertain.

Numerical nomenclature for the more important Illinois coal beds has become a system of naming by number, without much significance being attached to the numbers, except that care has been taken to have the beds so named by number that they are in the correct relative position. As used by the Illinois Geological Survey, the beds designated as No. 1, No. 2, No. 5, No. 6 and No. 7 designate in each case a bed occurring at a definite stratigraphic position.

While reference to the commercial coals of Illinois is commonly made by number, place names are sometimes employed, either in deference to past mining nomenclature before coal beds over the entire State were fully correlated, or for more specific locality identification. The following place names are frequently used, or have been used, to specify numbered coals from established mining districts:

Place Names of Numerically Designated Coal Beds

Numerical Designation of Bed	Place Name of Coal Bed
Coal No. 7	Danville Streator LaSalle 1st vein
Coal No. 6	Herrin Belleville LaSalle 2nd vein Grape Creek
Coal No. 5	Harrisburg Springfield Blair Rushville
Coal No. 2	LaSalle 3rd vein Colchester
Coal No. 1	Rock Island Murphysboro (A) Assumption (A)

Note: (A) Correlation with Coal No. 1 now considered doubtful.

Topography and Drainage

The surface topography of the area underlain by Illinois coal measures largely results from the effects of glacial erosion and deposition in the northern and central portions and from the effects of the Ozark uplift in the southern portion. The glaciated portion of the field is characterized by (1) broad river valleys; (2) dissected, interstream, glacial plains of the Illinoisan drift sheet in central and western Illinois; and (3) morainic ridges and intermorainic till plains of the later glacial stages in the northeastern portion of the field. In the southern area the erosion of folded and faulted strata has resulted in more or less irregularly disposed sandstone ridges and intervening valleys cut in shale.

The Mississippi River forms the entire western boundary of Illinois. The north-central and western portions of the State, however, are largely drained by the Illinois River and its principal tributaries, the Spoon and Sangamon Rivers. The south-central and southern portions of the State are largely drained into the Mississippi and Ohio Rivers by the Kaskaskia, Big Muddy, and Saline Rivers. The eastern portion of the State drains into the Wabash River, of which the Vermilion, Embarrass, and Little Wabash Rivers form the principal tributaries.

Sources of Information

The coal resources of Illinois have been the subject of relatively continuous surveys and investigations since the beginning of commercial mining around 1830. The Illinois State Geological Survey was established in 1851 and since that time has conducted widespread investigations, both individually and in cooperation with the U. S. Bureau of Mines and the Department of Mining Engineering of the University of Illinois, on coal occurrence and on its physical and chemical characteristics. The records and results of these continuing publications now afford a comprehensive knowledge of the coal resources of the State.

The Illinois Department of Mines and Minerals has compiled and published annual production statistics by mines and counties since 1882, these publications affording material information on locations, depths, and thicknesses of beds at mines in areas for which no other specific information is available. This Department also maintains copies of mine maps of current and abandoned underground operations for the major producing areas in the State, which provide a ready means of determining the extent of depleted areas in specific coal beds.

A series of strip-mine reconnaissance maps, prepared in 1946 and 1947 from aerial photographs by the Central States Forest Experiment Station, U. S. Department of Agriculture, indicates the location and extent of areas depleted by stripping over much of the State.

Additional information on extent and quality of coal beds in Illinois has been obtained from publications of the U.S. Bureau of Mines, the U.S. Geological Survey, the major railroads serving the coal-mining areas, and other organizations.

While the references described above generally contain the major amount of available information on the coal deposits of Illinois, other reports and investigations were examined throughout the survey.

Survey Methods and Procedure

In estimating the coal reserves of Illinois, all pertinent information available from the literature and other sources was posted on previously prepared base maps, with sources of information being appropriately indicated. Each base map covered an area consisting of one degree of longitude (east-west) and one-half degree of latitude (north-south) on a scale of 1:62,500. A separate print of each base map was used for each coal bed within the area, provided sufficient information was available to permit an evaluation of reserves.

Having posted all available information on outcrop, depth, and thickness of each bed on each base map area, including the extent of underground and strip-mine depletion, if present, the areas underlain by coal in each township for which specific data or any other types of relevant information were available were carefully analyzed and evaluated prior to delineation of classified areas of reserves. Individual areas depleted by underground or strip operations were demarcated and eliminated from further measurement by enclosure within a limiting line, located sufficiently far outside the outermost extents of the mined-out area to represent the limit of the probable barrier pillars which would be left between the depleted area and subsequent mining operations. Where individual depleted areas approached other depleted areas to such an extent that subsequent mining operations in the intervening areas would not be practical, as, in many areas of major depletion by groups of mines located relatively close together, the entire area was demarcated and eliminated from further measurement by a similar limiting line. Since the property lines toward which mining operations in active mines may be expected to proceed were not determined in this survey, it is probable that some portions of such intervening areas thus eliminated may be undergoing current depletion. The amounts of such reserves, which are considered relatively minor in extent, would thus not be included in the total amount of estimated reserves.

The delineation of measured, indicated, and inferred strippable reserves was based on detailed and individual examination of areas adjacent to the coal bed outcrop in each township containing such outcrop locations. Factors taken into account in

estimating the presence and extent of strippable reserves, included the distribution, frequency, and reliability of available information, the accuracy of location of the line of outcrop, the character of the slope immediately adjacent to the outcrop and the thickness of cover and width of the potential strippable area, as shown by topographic maps, if available, the character of the overburden, if known, and the size, shape, and extent of areas already depleted by stripping or shallow underground operations, if present. In estimating strippable reserves, the amount and character of the available information are relatively much more important than in estimating underground reserves, because of the determinative interdependence of factors, such as the thickness and continuity of coal bed and the thickness and character of overburden in a relatively small proportion of the general coal-bearing area.

An additional factor in estimating areas of strippable reserves is the economic relationship between the costs of recovery of reserves under relatively heavy cover by the stripping method and by underground mining. While the determination of reserves available for the manufacture of synthetic liquid fuels properly precedes any consideration of costs in this survey, it is considered relevant and proper to classify such areas of reserves as primary reserves for underground operation rather than as secondary reserves for strip-mine operation when it is estimated that underground mining will result in more economic recovery than strip mining. The inclusion of this factor in the several determinative criteria enumerated above has been adopted as a portion of the procedure followed in this survey.

Having demarcated and eliminated from further measurement all depleted areas and having delineated any areas of strippable reserves as described above, the remaining areas of reserves adjacent to such depleted and strippable areas and to outcrops, including any portions of the bed disclosed by drill hole or isolated shaft records, were classified by lines defining the various areas of measured, indicated, and inferred underground reserves as warranted by the available information and according to the definitions established in Part II of this report. Distinctions between primary and secondary underground reserves were based on average thicknesses of bed within each township.

Each classified area of reserves within each township, as thus delineated, was measured by planimeter to determine acreage, this figure then being multiplied by average thickness of the bed as developed from the data and by a constant of 1,800 tons per acre-foot, following U. S. Geological Survey procedure, to estimate the number of tons in place. The data on thickness of coal and cover and on acreage and quantity of reserves were then tabulated, by townships, on basic Coal Data Sheets*, with the information and estimated quantities of reserves in each township being grouped by individual beds in each county.

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*Complete sets of the basic Coal Data Sheets are available at the specific depositories listed in Exhibit No. 5.

Preliminary analysis of available data on Illinois coal deposits indicated that consideration of coal reserves as raw material for synthetic liquid fuels plant supply could best be conducted on individual coal beds in the specific counties underlain by such coal beds. Since it was found that information on minor coal beds either indicated that specific beds were too discontinuous or too thin for estimation of reserves according to the definitions employed in this survey, or were insufficient to permit any estimates of reserves, such beds were excluded from further consideration. The coal beds selected for further consideration, in descending order of stratigraphic occurrence, were as follows:

Coal No. 7
Coal No. 6
Coal No. 5
Indiana Coal No. 5(C)
Coal No. 2
Davis (A)
Willis (B)

Note: (A) In Saline and Gallatin Counties.
(B) In Gallatin County.
(C) In Edgar and Lawrence Counties.

Reserves of Indiana Coal No. 5, approximately correlative with Illinois Coal No. 5, extend westward from larger reserves in Indiana into southeastern Edgar and eastern Lawrence Counties.

Although the coal production of Illinois is frequently subdivided into nine major coal-producing districts in industrial practice, the use of districts as definite areas is commonly restricted to areas of producing mines. Reserves of individual coal beds removed from such productive areas would not commonly be recognized as portions of these districts. The analyses of available data on Illinois coal deposits, accordingly, were conducted by counties rather than by districts. Brief descriptions of the industrial coal-producing districts are presented in Exhibit No. 6.

Strip mining has been a major factor in Illinois coal production since 1925 and has exceeded 20 percent of total annual production since 1937. During this period the areas adjacent to the outcrops of the principal coal beds have been extensively stripped and even more extensively prospected for potential strip-mine operation. The result has been that the major portion of the strippable reserves of sizes adequate for consideration as synthetic liquid fuels plant supply, under the definitions followed in this survey, are now either in active operation or are held by present mining companies for future operation.

Under the definitions employed in this survey for delineating areas of measured, indicated, and inferred coal reserves, estimates of measured and indicated classes of reserves are largely based upon positive points of observation at maximum

intervals, as provided by the respective definitions. Estimates of inferred reserves, however, are based largely upon assumptions of extent, continuity, and thickness for which there is regional geologic evidence. While available evidence of continuity and persistence of individual coal beds has thus been taken into account in projecting areas of inferred reserves beyond areas of measured and indicated reserves, the resultant estimates are regarded only as provisional until further evidence from new or hitherto undisclosed exploration becomes available.

The information used in this survey was generally based on data from major sources such as Federal and State publications, railroads, coal trade associations, annual production statistics, etc. Neither time nor funds were available to this project for complete collection of all potential information in the hands of private interests. Since information from these sources would probably increase the usable information on extent of demonstrated coal reserves above that available from most publications, the estimated primary reserves in this survey would probably tend to become increased rather than decreased as when such additional information may become available in the future.

The diagram on the opposite page, has been prepared to indicate graphically the results of the previously described Survey Methods and Procedure, as these may appear on the individual base maps on which the various coal data are shown in detail.

Elimination of Counties Not Meeting Requirements of Survey

As indicated in the table which follows, there are 84 counties in Illinois which are entirely or in part underlain by coal-bearing strata. Six of these counties (second column of the table) were eliminated from further consideration, because preliminary investigation revealed them to be located in a fringe position too close to the outermost edge of the coal-bearing formation to contain appreciable minable areas of any of the coal beds.

The available information on each of the remaining 78 counties was then compiled by coal beds and examined in detail. After this detailed study it was found that there were 25 additional counties (third column of table) in which either reported isolated reserves were insufficient in amount to warrant consideration as synthetic liquid fuels plant supply or in which available information on depth, continuity, thickness and number of coal beds was insufficient to permit estimates of reserves. These counties were also eliminated from further consideration in this report, although detailed descriptions are given in Appendix A.

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DIAGRAM SHOWING PROCEDURES FOLLOWED IN CLASSIFYING AREAS OF RESERVES AS BASED ON AVAILABLE INFORMATION

SCALE OF MILES 1 0 1 2 3

LEGEND

Areas depleted by strip or underground mining

Shaft, drill hole, or outcrop record

T6N / T5N

T5N / T4N

R9W / R8W

R8W / R7W

MEASURED

Boundary of area considered as depleted

UNDERGROUND INFERRED

UNDERGROUND INDICATED

GEOLOGIC MAP

UNDERGROUND INFERRED

UNDERGROUND INDICATED

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09

The elimination of 31 counties as described above left 53 of the original 84 counties in which the coal reserves appeared to qualify as suitable for synthetic liquid fuels production. These counties are enumerated in the last column of the table, and a summary of their recoverable coal reserves is shown in Exhibit No. 7. The following section of the report describes the nature and extent of the coal beds in these counties and presents some data relating to present commercial production.

Selection of Counties in Illinois Containing Coal Reserves Suitable for Production of Synthetic Liquid Fuels

All Counties Containing Coal-bearing Strata	Counties Eliminated because of		Counties Selected as Suitable for Consideration
	Fringe Position near Outermost Limit	Isolated and Insufficient Reserves (A)	
Adams		Adams	
Bond			Bond
Brown		Brown	
Bureau			Bureau
Cass		Cass	
Champaign		Champaign	
Christian			Christian
Clark		Clark	
Clay			Clay
Clinton			Clinton
Coles		Coles	
Crawford		Crawford	
Cumberland		Cumberland	
DeWitt		DeWitt	
Douglas		Douglas	
Edgar			Edgar
Edwards			Edwards
Effingham			Effingham
Fayette			Fayette
Ford		Ford	
Franklin			Franklin
Fulton			Fulton
Gallatin			Gallatin
Greene			Greene
Grundy			Grundy
Hamilton			Hamilton
Hardin	Hardin		
Hancock		Hancock	
Henderson	Henderson		
Henry			Henry
Iroquois		Iroquois	
Jackson			Jackson
Jasper			Jasper
Jefferson			Jefferson

70321

Selection of Counties in Illinois Containing Coal Reserves Suitable for Production of Synthetic Liquid Fuels
(Continued)

All Counties Containing Coal-bearing Strata	Counties Eliminated because of Fringe Position near Outermost Limit	Counties Eliminated because of Isolated and Insufficient Reserves (A)	Counties Selected as Suitable for Consideration
Jersey			Jersey
Johnson		Johnson	
Kankakee			Kankakee
Knox			Knox
LaSalle			LaSalle
Lawrence			Lawrence
Livingston			Livingston
Lee	Lee		
Logan			Logan
Macon			Macon
Macoupin			Macoupin
Madison			Madison
Marion			Marion
Marshall			Marshall
Mason		Mason	
McDonough		McDonough	
McLean			McLean
Menard			Menard
Mercer		Mercer	
Monroe	Monroe		
Montgomery			Montgomery
Morgan		Morgan	
Moultrie		Moultrie	
Peoria			Peoria
Perry			Perry
Piatt		Piatt	
Pike		Pike	
Pope	Pope		
Putnam			Putnam
Randolph			Randolph
Richland			Richland
Rock Island		Rock Island	
Saline			Saline
Sangamon			Sangamon
Schuyler			Schuyler
Scott		Scott	
Shelby			Shelby
Stark			Stark
St. Clair			St. Clair
Tazewell			Tazewell
Union	Union		

Selection of Counties in Illinois Containing Coal Reserves Suitable for Production of Synthetic Liquid Fuels
(Concluded)

All Counties Containing Coal-bearing Strata	Counties Eliminated because of Fringe Position near Outermost Limit	Counties Eliminated because of Isolated and Insufficient Reserves (A)	Counties Selected as Suitable for Consideration
Vermilion			Vermilion
Wabash			Wabash
Warren		Warren	
Washington			Washington
Wayne			Wayne
White			White
Will			Will
Williamson			Williamson
Woodford		Woodford	

Note: (A) Descriptions of these counties rejected from further consideration for synthetic liquid fuels plant supply are included in Appendix A.

Description of Coal Reserves in Selected Counties

Bond County. (See Exhibit No. 4 for references below.) Bond County is located in the southwest portion of the Illinois coal field. The general dip of the coal beds is toward the south and east, although the presence of minor local folds may modify the direction of dip in some locations. No production was reported from Bond County in U.S. Bureau of Mines publication, M.M.S. No. 1807, "Bituminous Coal and Lignite in 1948". The last reported production in annual reports of the Illinois Department of Mines and Minerals was in 1937, although approximately 7,350,000 tons are indicated as having been produced in Bond County subsequent to 1882.

Available information on coal occurrences in Bond County indicates that there are substantial reserves of coal No. 6 and relatively limited reserves of coal No. 5, which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 is the principal bed in this county. Available information indicates that this bed underlies most of the entire county, but is not of sufficient thickness throughout, due to the presence of narrow cut-out areas in the northwestern portion of the county, in which the coal is either absent or less than 2 feet in thickness. Elsewhere, the coal averages 7 feet in thickness and has been mined at depths of approximately 400 feet. The estimated reserves of this coal in Bond County are contiguous with reserves

(References: 7, 31, 33)

in the same bed in Montgomery County to the north and in Clinton County to the south.

Coal No. 5 has been determined by drilling to underlie coal No. 6 in the northwestern portion of Bond County, where it has an average thickness of 5 ft 7 in. The relatively limited reserves in this area are contiguous with reserves of the same bed in southern Montgomery County and are suitable for further consideration in this survey.

Bureau County. (See Exhibit No. 4 for references below) Bureau County lies along the northern boundary of the coal measures in the northwestern portion of the Illinois coal field. The coal measures dip slightly toward the southeast in the western part of the county and toward the east in the eastern portion. Substantial portions of the county are covered with glacial material, which masks the coal bed outcrops. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in Bureau County for that year was obtained from the No. 6 bed. Bureau of Mines data on bituminous coal production in 1948 indicate that two strip mines produced approximately 686,000 tons in that year.

Available information on coal occurrences indicates that there are substantial reserves of No. 2 and No. 6 coal, which warrant further consideration as raw material for synthetic liquid fuels plant supply.

Coal No. 6 outcrops across the southwestern portion of the county, with thicknesses varying from less than 2 ft 0 in. to as much as 4 ft 8 in. The bed is commonly separated into two benches by a shale parting from 1/4 in. to 2 in. in thickness. While two strip operations are currently producing their output from this bed, the main portion of reserves in this county are available only by underground operation. The area of estimated reserves is adjacent to and contiguous with other reserves in this same bed in Henry and Stark Counties. Coal No. 6 has also been mined in eastern Bureau County and in western LaSalle County as the "second-vein bed" of the so-called "Longwall District" of northern Illinois. The available information indicates that reserves in the eastern area are too limited in extent to warrant further consideration.

Coal No. 5 underlies a small area in the extreme southeastern corner of Bureau County. This bed is highly irregular in thickness and continuity, with extensive areas in which the bed is replaced by sandstone. Elsewhere within the county this bed exists largely as a horizon marker, with limited areas in which the bed may thicken to from 1 ft 0 in. to 2 ft 0 in. The available information indicates that this bed is insufficient in extent to warrant further consideration.

(References: 2, 6, 10, 13, 31, 33)

Although Coal No. 2 is considered to underlie large portions of Bureau County, its former outcrop is now generally obscured by glacial drift. Scattered records indicate that the bed is commonly less than 2 ft 6 in. in thickness across the western and central portions of the county, but thickens to a maximum of 4 ft 10 in. in the eastern portion of the county, where this coal forms a part of the "Longwall District" in which the No. 2 bed was once widely mined. A substantial area of estimated reserves, with thicknesses ranging from 3 ft 4 in. to 3 ft 6 in., and at depths of approximately 450 feet, is present in the east-central portion of the county, where they are adjacent to and contiguous with similar reserves in the same bed in western LaSalle County and in northern Putnam County. These reserves are sufficient in extent to warrant further consideration in the production of synthetic liquid fuel.

Christian County. (See Exhibit No. 4 for references below) Christian County is located in central Illinois in the west-central portion of the coal field. The regional dip of the coal beds approximates 14 feet per mile toward the southeast, with minor local variations. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 7,980,000 tons were produced in Christian County in that year, entirely from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in this county was from the No. 6 bed.

Available information on coal occurrences in Christian County indicates that substantial reserves of coals No. 5 and No. 6 are present in sufficient extent to warrant further consideration as synthetic liquid fuels plant supply. While other coal beds are present, the information is either too limited, or indicates that such bedsare too irregular, to permit estimating of reserves.

Coals No. 8 and No. 7 occur persistently in drill-hole and shaft records across the county, but are generally limited to less than 2 ft 0 in. in thickness, being considered largely as horizon markers. The available information indicated that these beds are insufficient in thickness to warrant further consideration.

Coal No. 6 has been mined in, and underlies most of, the north-central portion, and a substantial area in the southeastern portion, of the county. A large barren area separates these two portions of the No. 6 bed reserves, in which the coal was either never deposited or was removed by erosion after deposition, with later deposition of sandstone and shale at the original coal horizon. This barren area extends into Shelby County on the east and into Montgomery County on the southwest. Coal No. 6 thins

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(References: 7, 13, 24, 26, 31, 33)

and disappears toward the north at about the south line of the northernmost three townships in Christian. This line, together with its westward continuation into Sangamon County, marks the northern limits of the No. 6 coal bed of southern Illinois. This bed reappears to the north in Tazewell, Peoria, and Fulton Counties.

In the two separate coal-containing portions of Christian County, coal No. 6 varies from 3 ft 7 in. to 9 ft 9 in. in thickness, averaging approximately 7 ft 0 in. in the northern portion and approximately 8 ft 0 in. in the southeastern portion. The coal bed varies in depth from approximately 300 feet in the northwestern portion of the county to approximately 700 feet in the southeastern portion. The northern area of reserves is adjacent to and contiguous with reserves of the same coal in southern Sangamon County and in northern Montgomery County. The southeastern area of reserves is adjacent to and contiguous with other reserves of the same coal in southwestern Shelby County and in northeastern Montgomery County. These two areas of reserves are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 underlies the northern portion of the county, where it varies from 4 ft 2 in. to 7 ft 7 in. in thickness and ranges in depth from 310 to 675 feet below the surface. The southern line of this area, together with its westward extension into Sangamon County, marks the southern limits of the workable No. 5 coal of central Illinois. The available information indicates that there are sufficient reserves of this coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 2 has been encountered in the deeper drill holes and it is believed that an abandoned deep mine in the northeast corner of the county was working in a lower bench of this bed. Information on this coal is too limited to establish sufficient extent so as to warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 1 is considered to have been worked at one mine near the center of the east line of the county, at a depth of 1,004 feet below the surface, the deepest mine in the State. The average thickness of coal in this mine was 3 ft 6 in. The available information is too limited to permit estimates of reserves.

Clay County. (See Exhibit No. 4 for references below) Clay County is located in the southeast portion of the Illinois coal field, where the coal-bearing strata occur near the axis of the deepest trough of the Illinois coal basin. The general dip of the

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(References: 25, 31, 33)

coal beds is toward the east. No production has been reported from Clay County by either the Bureau of Mines or the Illinois Department of Mines and Minerals.

Available information on coal occurrences in Clay County indicates that there are substantial reserves of coal No. 5 and coal No. 6, which warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 6 underlies approximately the eastern half of the county. While no coal has been mined from Clay County, the presence of coal No. 6 has been extensively determined by numerous oil tests, which have been put down through the coal horizon during the past ten years. Many of these oil tests were examined during drilling by members of the Illinois Geological Survey, who determined the depth and thickness of the coal beds encountered in the drilling process. Coal No. 6 occurs at depths ranging from 960 to 1,140 feet below the surface, with thicknesses varying from 2 ft 0 in. to 4 ft 0 in. While the numerous drill holes indicate the presence of the coal bed and its approximate thickness, the information derived from such drilling does not indicate the quality of the coal or the physical characteristics of the roof, coal bed, and floor. Such available information indicates, however, that Clay County contains sufficient reserves of the No. 6 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 likewise has been shown by oil tests to underlie large areas in Clay County. The depths of this bed range from 885 to 1,185 feet below the surface, and the coal bed varies from 1 ft 0 in. to 4 ft 0 in. in thickness. While the numerous drill holes do not disclose the quality of the coal nor the physical characteristics of the roof, coal bed, and floor, they are sufficient in extent to indicate the presence of sufficient reserves to warrant further consideration as synthetic liquid fuels plant supply.

Clinton County. (See Exhibit No. 4 for references below) Clinton County is located in the southwestern portion of the Illinois coal field. The general dip of the coal beds is toward the east, although the presence of minor local folds may modify the direction of dip at some locations. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 296,000 tons were produced in Clinton County in that year, all of which was from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948, indicates that the entire production in this county was from the No. 6 bed.

(References: 7, 24, 31, 33, 36)

Available information on coal occurrences in Clinton County indicates that substantial reserves of coal No. 6 and relatively limited reserves of coal No. 5 are present in sufficient extent to warrant further consideration as synthetic liquid fuels plant supply. While other coal beds are present, the information is either too limited or indicates that such beds are too irregular to permit estimating of reserves.

Coals No. 8 and No. 7 have been found in a few scattered drill holes across the county, but are generally less than 2 ft 0 in. in thickness and are considered largely as horizon markers. The available information on these beds is insufficient to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 is indicated by mine and drill-hole information to underlie all of Clinton County except the northeast and northwest corners. The depth of this bed varies from approximately 225 feet near the west line of the county, to approximately 550 feet on the east line. The coal has been mined extensively in the western part of the county by shaft operations, the deepest of which was 440 feet below the surface, located approximately in the center of the county. Where present, coal No. 6 averages approximately 7 ft 0 in. in thickness. The available information indicates that a narrow, north-south strip, from 1 to 2 miles in width, extends in a north-south direction along the western line of the county, in which the coal bed is either absent or of limited thickness. Sufficient information is not available to indicate the continuity of the bed in the northeastern portion of the county. Elsewhere, the bed is persistent in character and exhibits approximately the same mining characteristics common to this bed in southwestern Illinois. While substantial areas of the No. 6 coal have been depleted in the eastern part of the county, sufficient estimated reserves are present to warrant further consideration as synthetic liquid fuels plant supply.

Coals No. 5 and No. 2 occur in Clinton County. A large proportion of the drill-hole information terminates in the underclay of the No. 6 coal. In consequence, the possible occurrence of coal beds below the No. 6 bed has not been thoroughly developed. Coal No. 5 has been determined by drilling to underlie coal No. 6 in a relatively small area in central western Clinton County. Coal No. 2 has been encountered in scattered drill-hole locations across the county, but the available information is too limited to permit any estimates of reserves for this bed.

Edgar County. (See Exhibit No. 4 for references below.) Edgar County is located approximately in the center of the eastern line of counties in the Illinois coal field. The general dip of the coal beds is toward the southwest. Bureau of Mines data on

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(References: 3, 31, 33)

bituminous coal production for 1948, indicate that approximately 28,000 tons were produced by underground mining from Edgar County in that year. The annual report of the Illinois Department of Mines and Minerals for 1948 does not indicate the bed correlation.

The available information on coal occurrences in Edgar County indicates that substantial reserves of Indiana coal No. 5 extend into the southeastern portion of Edgar County from the mining districts of southwestern Vermilion County and northwestern Vigo County in Indiana. Limited information indicates that this bed varies from 4 ft 0 in. to 6 ft 0 in. in various portions of the county and that the reserves are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Limited drill-hole information indicates that other Indiana coal beds may also extend into Edgar County from the east. These beds have been tentatively correlated with the No. 6 and the No. 3 beds of Indiana, but the available information is too limited to permit the estimating of any reserves for these beds. It is probable that information not now available, as well as information which will probably be obtained in the future, may result in establishing substantial areas of reserves of one or more coal beds in eastern Edgar County.

Edwards County. (See Exhibit No. 4 for references below) Edwards County is located in the southeastern portion of the Illinois coal field, with the southeastern corner of this county bordering on the Wabash River which forms the eastern boundary of the State in this area. The coal measures occur along or near the central axis of the deepest portion of the Illinois coal trough. The regional dip of the coal beds is toward the west. No production has been reported from Edwards County by the Bureau of Mines or the Illinois Department of Mines and Minerals.

The available information on coal occurrences in Edwards County is largely confined to that supplied by the drilling of numerous oil tests, which have been made during the past decade in this portion of Illinois. The drilling of a substantial number of the oil tests was accompanied by close examination and observation by members of the Illinois Geological Survey. A number of the drill-holes encountered one or more coal beds at depths ranging from 850 to nearly 1,500 feet below the surface in this county. The uppermost of these beds occurs approximately from 850 to 1,000 feet in depth and is reported to range from 3 ft 0 in. to 4 ft 0 in. in thickness. It is believed that this is the Illinois No. 6 bed. A second bed, tentatively correlated with the No. 5 coal and ranging from 3 ft 6 in. to 5 ft 0 in. in thickness, is frequently present at intervals of from 75 to 100 feet below the No. 6 bed.

(References: 25, 31, 33)

A still deeper coal bed was encountered approximately 300 feet below the No. 6 bed. The information on the latter bed, however, is insufficient to permit correlation or estimates of any possible reserves.

The oil-test drilling is sufficiently uniform to permit the estimates of small areas of reserves of the No. 6 and the No. 5 beds in the extreme southeastern corner of Edwards County where they are adjacent to and connected with reserves of the same beds in southeastern Wayne County.

Effingham County. (See Exhibit No. 4 for references A below) Effingham County lies in the south-central portion of the Illinois coal field, with the coal-bearing strata occurring approximately in the central or deepest portion of the Illinois coal trough. No production was reported from Effingham County in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. A very small amount of coal has been mined from Effingham County in the 66 years of record from 1882 to 1948 by the Illinois Department of Mines and Minerals. This production is considered to have been obtained from shallow, uncorrelated beds which occur near the surface in portions of the county.

A small number of oil tests have been examined during their drilling by members of the Illinois Geological Survey, and workable beds were observed in each such test. The uppermost of these beds is tentatively correlated with the No. 6 bed and occurs at depths of from 525 to 760 feet below the surface. An underlying bed, occurring at depths of from 610 to 945 feet below the surface, has been tentatively correlated with the No. 5 bed. The information is too limited to permit estimates of reserves in this county except in the extreme southern margin of the county, where small areas of No. 6 and No. 5 coal are present at locations adjacent to and connected with larger areas of reserves of the same beds in northern Clay County.

Fayette County. (See Exhibit No. 4 for references B below) Fayette County is located in the south-central portion of the Illinois coal field. The regional dip of the coal beds is toward the east. No production has been reported from Fayette County by the Bureau of Mines or the Illinois Department of Mines and Minerals.

The available information on coal occurrences in Fayette County indicates that substantial reserves of coal No. 6 and relatively limited reserves of coal No. 5 are present in sufficient extent in the northwestern portion of the county to warrant further consideration as synthetic liquid fuels plant supply.

(References A: 25, 31, 33)
(References B: 7, 26, 31, 33)

Coal No. 6 underlies the northwestern third of Fayette County, where it is adjacent to and connected with larger areas of reserves of the same bed in eastern Montgomery County, northeastern Bond County, and southwestern Shelby County. In this area, the bed averages 6 ft 6 in. in thickness. The available information indicates that the bed tends to thin and become irregular toward the central and southeastern portions of the county. The information on occurrence and continuity is limited to the evidence of scattered drilling. This information is sufficient, however, to indicate the presence of substantial reserves.

Coal No. 5 has been determined by drilling to underlie a small area in the northwestern and southeastern portion of the county, where it ranges from 2 ft 6 in. to 4 ft 0 in. in thickness, and occurs at depths from 600 to 900 feet below the surface.

Other irregular coal beds have been penetrated at scattered locations over the county by the drilling to the No. 6 bed. Such information is too limited to permit the estimation of reserves for any other bed in this county.

Franklin County. (See Exhibit No. 4 for references below.) Franklin County lies in the southern portion of the Illinois coal field. The regional dip of the coal beds is toward the north and northeast. The western boundary of Franklin County is marked by a sharp anticlinal fold, which extends in a north-south direction across the eastern edge of Perry County and raises the coal beds from depths of 400 feet or more over most of the county to positions very close to the surface at the crest of the anticline. A zone of predominately northwest-southeast faulting extends in a general east-west direction across the southern portion of the county. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 12,801,000 tons were produced in Franklin County in that year, all of which was obtained from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from Franklin County was obtained from the No. 6 coal bed.

Available information on coal occurrences in Franklin County indicates that substantial reserves of No. 6 coal are present in the northeastern portion of the county in sufficient extent to warrant further consideration as synthetic liquid fuels plant supply. In addition, a substantial amount of No. 5 coal is present in the southwestern corner of the county, where reserves of this bed are adjacent to, and contiguous with, larger reserves of the same bed in southeastern Perry County, northeastern Jackson County and northwestern Williamson County. These reserves are likewise sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

(References: 4, 20, 31, 33, 36)

Coal No. 6 has been extensively mined in the southwestern third of Franklin County, where this bed occurs at depths of from 200 to 500 feet below the surface. In this mined-out area, the bed ranged from 6 ft 0 in. to over 12 ft 0 in. in thickness, averaging approximately 8 ft 6 in. As originally deposited, large areas of coal No. 6 in southwestern Franklin County contained some of the highest quality coal in the Illinois coal field. The quality of the remaining reserves is relatively inferior.

Mining operations in southwestern Franklin County have been somewhat curtailed by the presence of a relatively large, oval-shaped area extending in an east-west direction across a portion of the field in which coal No. 6 was either never deposited or was eroded after deposition and subsequently refilled with sandstone and shale. This area is designated as the "Mulkeytown Split" and has been well defined by mining operations around its northern, eastern, and southern perimeter.

The remaining reserves in Franklin County are deeper and tend to be of poorer quality than the average coal which has been mined from the southwestern portion of this county. The available information indicates that the thickness of these reserves ranges from 5 ft 3 in. to 10 ft 6 in. The bed occurs at depths of approximately 700 feet along the northeastern boundary of the county, from which it gradually raises toward the central and southern portions of the county. These reserves, even though remaining behind substantial depleted areas, are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 occurs from 40 to 80 feet below Coal No. 6 in Franklin County. Where encountered by drilling, this bed ranges from 3 ft 6 in. to 5 ft 6 in. in thickness. This bed has not been mined in Franklin County because of the presence of the thick, high quality No. 6 coal above it. Substantial reserves of this bed are present in the southwestern portion of Franklin County, however, where they adjoin and are connected with larger reserves of the same bed in adjacent counties. While this bed underlies worked-out mines in the overlying No. 6 bed, it is considered that the reserves are sufficient in extent, continuity, and minability to warrant further consideration as synthetic liquid fuels plant supply.

The numerous drill holes to the No. 6 and No. 5 coals in Franklin County have encountered thin, irregular beds of coal at various intervals above the principal commercial bed. Such information is too limited to permit the estimating of reserves for these coals. A few deep drillings within Franklin County also indicate the presence of thin and irregular beds below the No. 5 bed, but the information on such occurrences is too limited to permit the estimating of reserves.

Fulton County. (See Exhibit No. 4 for references below) Fulton County is located in the northwestern portion of the Illinois coal field. The regional dip of the coal beds is toward the east. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 5,744,000 tons were produced in Fulton County in that year, of which approximately 5,457,000 tons were produced from 10 stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948, indicates that approximately 85 percent of the production of Fulton County was obtained from the No. 5 bed, with 15 percent being obtained from the No. 6 bed.

The available information on coal occurrences in Fulton County indicates that substantial reserves of coals No. 6 and No. 5 are present in sufficient extent to warrant further consideration as synthetic liquid fuels plant supply. While other coal beds are present, the information is either too limited, or indicates that such beds are too thin to permit the estimating of reserves.

The No. 6 bed occurs near the surface in the northeastern corner of Fulton County where it has been mined extensively by stripping and by relatively small underground operations. This bed averages 3 ft 6 in. in thickness. Although extensively depleted, some reserves are considered to remain in the northeastern corner of the county, where they adjoin reserves in the same bed in southeastern Knox County. Coal No. 6 becomes thin and highly impure toward the east and is not minable in the western portion of Peoria County immediately east of Fulton County.

The No. 5 coal underlies large areas in the northeastern portion of Fulton County, where it has been extensively mined, both by underground and stripping operations. While this bed normally occurs from 50 to 65 feet below the No. 6 bed, the two beds are virtually in contact in local areas. Coal No. 5 varies from 3 ft 5 in. to 4 ft 6 in. in thickness and is persistent in nature. The bed is characterized, however, by irregular, vertical partings of shale, ranging from a few inches to several feet in thickness, which intersect the coal bed and must be handled in the mining operations. These vertical partings are commonly known as "horsebacks". Although extensively mined, substantial areas of reserves remain in the northeastern portion of Fulton County, where they adjoin and are connected with smaller areas of reserves of the same bed in southeastern Knox County. The continuity of the No. 5 coal east of Fulton County is interrupted by a large north-south cutout, which lies mainly in southwestern Peoria County, but extends into a portion of eastern Fulton County.

(References: 6, 10, 24, 31, 33, 36)

Coal No. 2 outcrops in a northeast-southwest direction across the southeastern portion of Fulton County, where it has been mined by small local operations. The available information on this bed is too limited to permit the estimating of reserves.

Coal No. 1 occurs in local areas in the central part of Fulton County. While sometimes occurring in thicknesses up to 4 ft 0 in., this bed is very erratic in thickness and in continuity. The available information indicates that this bed is too limited in occurrence and extent to warrant further consideration in this survey.

Gallatin County. (See Exhibit No.4 for references below) Gallatin County is located in the southeast portion of the Illinois coal fields, where it is bordered on the northeast by the Wabash River and on the southeast by the Ohio River. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 71,000 tons of coal were produced in Gallatin County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in this county was from the No. 5 bed.

The coal-bearing area in Gallatin County is composed of two separate coal fields, the northernmost of which underlies the northern two-thirds of the county and forms a portion of the margin of the main Illinois coal field. The prevailing dip of the coal beds in this northern area is toward the north, with local interruptions due to a belt of faulting extending in an east-west direction near the southern limit of this coal-bearing area. The second coal-bearing area in Gallatin County is restricted to a narrow east-west syncline extending across the southern tier of townships into the southeastern corner of Saline County. This area is separated from the main northern area by pronounced faulting, and the syncline also contains minor folding and faulting associated with the formation of the syncline. This latter area is commonly known as the Eagle Valley syncline.

Available information on coal occurrences in Gallatin County indicates that substantial reserves of beds No. 5 and No. 6 are present in sufficient extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 solidly underlies the northern coal-bearing area, the outcrop extending in an east-west direction slightly south of the center of the county. This bed varies from 2 ft 0 in. to 7 ft 0 in. in thickness and dips away from the outcrop to as much as 670 feet below the surface near the north line of the county. The bed has been mined by small local operations

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(References: 5, 12, 13, 20, 31, 33, 36)

adjacent to the outcrop. These operations, together with drill holes which were put down to test the underlying No. 5 bed in areas of deeper cover, are sufficient to indicate the presence of substantial areas of reserves which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 outcrops in an east-west direction parallel with and slightly south of the outcrop of the No. 6 bed. This coal varies from 4 ft 0 in. to 8 ft 0 in. in thickness and reaches a depth of approximately 700 feet below the surface along the northern line of the county. This bed has been extensively mined in Saline County to the west, and in the southwestern portion of the area underlain by this bed in Gallatin County. Substantial reserves are present, however, in the western and northwestern portion of the northern coal-bearing area and are sufficient in amount and extent to warrant further consideration as synthetic liquid fuels plant supply.

The Eagle Valley syncline contains at least four workable coal beds, the uppermost of which is correlated with the No. 6 bed of the main Illinois coal field to the north. This syncline also contains the No. 5 bed and two lower beds which have been named the Davis and Willis coals. Each of these four beds has been opened near their outcrops for local consumption. The available information, however, indicates that limited reserves of the Davis and Willis coals warrant further consideration as synthetic liquid fuels plant supply.

Greene County. (See Exhibit No. 4 for references below) Greene County is located in the west-central portion of the Illinois coal field, along the western margin of the coal-bearing basin east of the Illinois River. The regional dip of the coal beds is toward the east. No production was reported from this county in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. Approximately 620,000 tons are indicated to have been produced from this county during the period from 1882 to 1948.

The available information on coal occurrences in Greene County indicates that there are small areas of coal No. 6 which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 outcrops in a north-south direction across the center of Greene County and is considered to underlie approximately the eastern half of the county. Small shaft operations have been put down to this bed at depths commonly less than 100 feet. The bed ranges from 2 ft 8 in. to 7 ft 0 in. in thickness but is irregular in both thickness and continuity where it has been mined. Isolated areas of reserves are present along the eastern county line, and in the southeast corner of the county with

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(References: 6, 13, 31, 33, 36)

thicknesses ranging from 5 ft 3 in. to 6 ft 0 in. These areas are not connected with larger areas of reserves either in Greene County or in Macoupin County to the east. Reserves along the eastern county line are insufficient in amount to be included in a General Area of Coal Availability as defined for this survey, while those in the southeastern corner were too small to merit further consideration.

Coal No. 2 also outcrops in a north-south direction across the central portion of Greene County, west of the outcrop of coal No. 6. While relatively persistent, this bed averages less than 2 ft 0 in. in thickness and has only been opened by small local operations. The available information is insufficient to permit the estimating of reserves and suggests that the bed is too thin to warrant further consideration for the production of synthetic liquid fuels.

Grundy County. (See Exhibit No. 4 for references below.) Grundy County is located in the northeastern portion of the Illinois coal field, on the margin of the coal-bearing formations. The general dip of the coal beds is toward the south and west. In the Bureau of Mines report on bituminous coal production for 1948, the production from Grundy County is combined with production from Will County, which is located directly east of Grundy County. The reported production for the two counties was 1,835,000 tons which was entirely obtained from four stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 170,000 tons were produced in Grundy County in that year, largely from the No. 2 bed.

Available information on coal occurrences in Grundy County indicates that there are substantial reserves of coal No. 2 which warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 7 underlies a small area in the southeast corner of Grundy County where it is being stripped at a local operation. The available information on thickness and continuity of this bed is insufficient to permit estimates of reserves.

Coal No. 2 outcrops in a northwest-southeast direction across the northern portion of Grundy County, swinging toward the west along the northern line of the county. This bed was extensively mined by underground operations ranging up to 150 feet in depth in former years. Except for small local underground operations, however, the bed is now largely being mined by stripping in areas adjacent to the outcrop. The No. 2 bed ranges from 2 ft 0 in. to 4 ft 0 in. in thickness with a few irregular channel-shaped areas in which the bed attains a local thickness of approximately 6 ft 0 in. Substantial areas of underground reserves are present in sufficient amount to warrant further consideration for synthetic liquid fuels plant supply.

(References: 2, 13, 31, 33, 36)

Hamilton County. (See Exhibit No. 4 for references A below) Hamilton County is located in the southeastern portion of the Illinois coal field in which the coal measures lie in the deepest parts of the Illinois basin. The general dip of the coal beds is toward the north and northeast. No production was reported from Hamilton County by the Bureau of Mines or the Illinois Department of Mines and Minerals for 1948. A very small amount of production has been reported from Hamilton County prior to 1948, which was probably obtained from mines extending into the southwest corner of the county from Saline County or Franklin County to the south.

Available information on coal occurrences in Hamilton County indicates that there are substantial reserves of coal No. 5 and No. 6 which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 is indicated by scattered drill holes to underlie most of the county except the northern portion. The coal bed occurs at depths ranging from approximately 525 feet below the surface in the southern part of the county to over 900 feet below the surface in the northern part. The bed ranges from 3 ft 0 in. to 9 ft 1 in. in thickness. Although the drill-hole information is sufficient to indicate substantial areas of reserves, the resulting information on quality and on physical characteristics of the roof, coal bed, and floor is limited.

Coal No. 5 is likewise indicated by drill holes to underlie substantial areas in the southern half of Hamilton County. The bed ranges from 3 ft 6 in. to 7 ft 8 in. in thickness, although the available information on quality and on physical characteristics of roof, coal bed, and floor is limited. The estimated reserves are sufficient in amount to warrant further consideration for synthetic liquid fuels plant supply.

Henry County. (See Exhibit No. 4 for references B below) Henry County is located in the northwestern portion of the Illinois coal field, along the northern margin of the coal-bearing formations. The general dip of the coal beds is toward the south and southeast. This county has been glaciated and the obscuring mantle of glacial deposits has hampered the mapping of coal bed outcrops. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 111,000 tons were produced from Henry County in that year, entirely by underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the majority of production in this county was obtained from the No. 1 coal in that year.

Available information on coal occurrences in Henry County indicates that there are substantial reserves of the No. 6 bed, and relatively minor reserves of the No. 2 coal, which are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

(References A: 7, 13, 18, 31, 33)
(References B: 10, 24, 31, 33, 36)

Coal No. 6 underlies approximately the southeastern quarter of Henry County. This bed has been mined at a number of scattered locations by shallow, underground operations. The bed ranges from 3 ft 0 in. to 5 ft 6 in. in thickness, but contains numerous interlaminated partings, as well as material projected into the coal seams from roof or floor. The estimated reserves of this bed in Henry County are contiguous with reserves in the same bed in Bureau, Knox, and Stark Counties toward the southeast.

Coal No. 2 outcrops in a general southwest-northeast direction across the central portion of Henry County. It has been opened by local drift mines along the outcrop and has also been extensively stripped by one large operation in the east-central part of the county. The thickness of this bed ranges from 2 ft 6 in. to 3 ft 8 in., but averages only 2 ft 8 in. in thickness. A relatively small area of reserves is estimated to be present in the east-central portion of the county adjacent to the stripped-over area. Elsewhere within the county, the information is too limited to permit estimates of reserves.

Coal No. 1 occurs in minable deposits in the extreme northwestern part of the county and in a small area in the southwestern portion. This bed characteristically occurs in relatively small, elongated troughs in which the bed may attain a maximum thickness of 5 ft 0 in., but in which the bed tapers rapidly to less than 2 ft 0 in. in thickness around the margins of the deposits. The available information indicates that reserves of No. 1 coal in such small areas are too limited to warrant further consideration in this survey.

Jackson County. (See Exhibit No. 4 for references below) Jackson County is located in the southwestern portion of the Illinois coal field, along the margin of the coal-bearing formations. The general dip of the coal beds is toward the northeast, although the bed also rises gently toward the crest of the north-south Duquoin anticline, which extends along the east line of the county and from which the beds dip rapidly toward the lower elevations occurring in Williamson and Franklin Counties to the east. Bureau of Mines data on bituminous coal production in 1948 indicates that 1,240,000 tons were produced in Jackson County in that year, of which approximately 399,000 tons were produced from two stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 70 percent of total production for that year was obtained from the No. 6 bed, with the remaining production being obtained from the No. 5 bed.

(References: 11, 20, 31, 33, 36)

Available information on coal occurrences in Jackson County indicates that there are substantial reserves of the No. 5 bed and relatively minor reserves of the No. 6 bed which are sufficient in amount to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 originally underlaid substantial portions of the northeastern corner of Jackson County. The major portion of this area has been depleted by both underground and stripping operations. In this area, coal No. 6 averaged 7 ft 0 in. in thickness. A small area of reserves is present near the north line of this county where these reserves are adjacent to and contiguous with a larger area of reserves of the same bed in eastern Perry County.

Coal No. 5 underlies a large area in the northeastern portion of Jackson County, where it outcrops in a northwest-southeast direction. The bed ranges from 4 ft 0 in. to 5 ft 2 in. in thickness and dips from the outcrop to a maximum depth of 300 feet below the surface in the northeast corner of the county. The bed has been mined near the outcrop by relatively small operations and extensive reserves are indicated to be present northeast of the outcrop. While the overlying No. 6 coal has been mined out above the No. 5 bed, the estimated reserves of the latter bed are sufficient in amount to warrant further consideration as synthetic liquid fuels plant supply. These reserves are adjacent to and contiguous with other reserves of the same bed in southeastern Perry County, southwestern Franklin County, and northwestern Williamson County.

A coal bed commonly designated as the "Murphysboro" bed formerly occurred in the east-central portion of Jackson County where its superior quality was early recognized, with the result that the limited area underlain by this bed has been largely exhausted. The bed reached a maximum thickness of 6 ft 0 in. but diminished in thickness away from the area of thick coal occurrence to less than 2 ft 0 in. While formerly correlated with the Illinois No. 2 bed, it has been later considered as representing a coal horizon approximately at the same stratigraphic position as the Illinois No. 1 bed. The available information indicates that remaining reserves of this deposit are too limited in extent to warrant further consideration in this survey.

Jasper County. (See Exhibit No. 4 for references below) Jasper County is located in the southeast-central portion of the Illinois coal field, where it occupies a position over the deepest part of the Illinois coal basin. No production from this county has been reported by the Bureau of Mines or the Illinois Department of Mines and Minerals for 1948. The very small production reported from this county in years prior to 1948 was probably obtained from thin, irregular beds occurring near the surface in the eastern part of the county.

(References: 2, 25, 31, 33)

The only available information on coal bed occurrences in Jasper County has been obtained from deep oil tests which have been made during the past 10 years in this portion of Illinois. These tests indicate the presence of at least two coal beds at depths ranging from 1,000 to 1,200 feet below the surface. The correlation of the coal beds indicated by such drilling is doubtful, but sufficient evidence from such drilling is present to warrant the estimation of a limited amount of reserves of No. 5 coal in the southwestern corner of the county where these reserves are contiguous with larger reserves of the same bed in northeastern Clay County.

Jefferson County. (See Exhibit No. 4 for references below) Jefferson County is located in the south-central portion of the Illinois coal field. The general dip of the coal beds is toward the northeast. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 571,000 tons were produced in Jefferson County in that period, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in Jefferson County for that year was obtained from the No. 6 bed.

Available information on coal occurrences in Jefferson County indicates that there are substantial reserves of No. 6 coal and relatively minor reserves of No. 5 coal which are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 solidly underlies the southwestern two-thirds of Jefferson County. This bed ranges from 4 ft 8 in. to 10 ft 8 in. in thickness and from approximately 600 to 900 feet in depth below the surface, with the deeper portion of the bed being located along the northern line of the county. While a limited number of abandoned and active shaft operations are located in the southern part of the county, the entire coal-bearing area has been extensively explored by drilling. The available information indicates the presence of substantial reserves in this bed which are suitable for further consideration for synthetic liquid fuels plant supply.

Coal No. 5 has been identified in drill holes at vertical intervals ranging from 40 to 100 feet below the No. 6 bed. This bed ranges from 3 ft 0 in. to 7 ft 0 in. in thickness. Although indicated as present by such drilling, the number and frequency of the drill holes are too limited to permit estimates of reserves in this bed over most of the county. Relatively small areas of reserves in this bed, however, are indicated by more closely spaced drill holes to be present in the northeastern corner of the county, where they adjoin and are contiguous with reserves of the same bed in western Wayne County to the east.

(References: 4, 20, 31, 33, 36)

Deeper coal beds have been found in a few irregularly spaced drill holes below the No. 5 bed. These beds have not been correlated with the principal beds of the Illinois coal basin, and the available information is too limited to permit estimates of reserves. Similarly, irregular thin beds have been found in the drill holes above the No. 6 coal. These are not known to be persistent and usually occur in thicknesses of less than 2 ft 0 in. The available information is insufficient to permit any estimates of reserves for such coal occurrences.

Jersey County. (See Exhibit No. 4 for references below.) Jersey County is located in the southwestern portion of the Illinois coal field, along the margin of the coal-bearing formations east of the Illinois River. The general dip of the coal beds is toward the east. No production was reported from Jersey County in 1948 by the Bureau of Mines. The annual report of the Illinois Department of Mines and Minerals indicates a production of less than 500 tons from one local operation in Jersey County in 1948. The Illinois Department of Mines and Minerals annual report also indicates a total production of approximately 119,000 tons during the period of record from 1882 to 1948.

The available information on coal occurrences in Jersey County indicates that there are sufficient reserves in the No. 6 coal in this county to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 outcrops in a north-south direction across the eastern portion of Jersey County. It has been worked sporadically at small local operations, ranging up to approximately 75 feet in depth. The available information from such local operations and from scattered drill holes indicates that the thickness of this bed ranges from 2 ft 10 in. to 3 ft 9 in., with the thicker coal occurring largely in the southeastern corner of the county. The information is too limited to indicate that the bed has sufficient continuity and thickness to permit estimates of reserves over most of the county. A relatively small area of reserves, however, is present near the southeastern corner of the county and is sufficient in extent to warrant further consideration in this survey.

Coal No. 2 probably outcrops in a north-south direction west of the outcrop of the No. 6 bed. The outcrop has been opened by a few small local operations, but the available information is not sufficient to establish the continuity of this bed, even along the outcrop. Where opened for local supply, the bed averages approximately 2 ft 0 in. in thickness. The available information is too limited to permit any estimates of reserves for this bed.

(References: 10, 31, 33, 36)

Kankakee County. (See Exhibit No. 4 for references A below) This county is located in the northeastern portion of the Illinois coal field along the margin of the coal-bearing formations in that area. Only the western tier of townships is underlain by coal-bearing strata in this county. The general dip of these coal-bearing beds is toward the southwest. No production was reported from this county in 1948 by the Bureau of Mines or by the Illinois Department of Mines and Minerals. The last reported production in annual reports of the Illinois Department of Mines and Minerals was in 1910, although it is indicated that nearly 2,000,000 tons have been produced from this county subsequent to 1882.

The available information on coal occurrences in Kankakee County indicates that there are sufficient reserves of No. 2 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 7 underlies a very small area in the northwestern corner of Kankakee County and is being worked by a local operation in an adjoining area in southeastern Grundy County. The available information indicates that reserves of this bed are too limited in extent and continuity to warrant further consideration in this survey.

Coal No. 2 underlies the western portion of the coal-bearing areas in Kankakee County and has been worked to a limited extent by relatively shallow underground operations. This bed varies from 2 ft 7 in. to 4 ft 10 in. in thickness and adjoins larger areas of reserves of the same bed in southwestern Will County, southeastern Grundy County, and northeastern Livingston County. The available information indicates that sufficient reserves of coal No. 2 are present to warrant further consideration for synthetic liquid fuels plant supply.

Knox County. (See Exhibit No. 4 for references B below) Knox County is located in the northwestern portion of the Illinois coal field. The general dip of the coal beds is toward the southwest. This county has been glaciated, and the outcrops of the coal beds have been partially obscured by irregular thicknesses of glacial deposits. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 2,147,000 tons were produced in this county in that year, of which approximately 2,018,000 tons were obtained from three stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicated that approximately 45 percent of the total county production in that year was obtained from the No. 6 bed, with 55 percent being obtained from coal No. 5.

(References A: 2, 13, 31, 33, 36)
(References B: 6, 10, 24, 31, 33, 36)

The available information on coal occurrences in Knox County indicates that substantial reserves of both No. 5 and No. 6 coals are present which are sufficient in amount to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 underlies a relatively large east-west ridge which extends across the north-central portion of Knox County. The coal in this area has been partially depleted by one stripping operation and by relatively small, shallow underground operations. This bed also occurs in a relatively small area in the southeastern corner of the county, where it adjoins and is contiguous with larger reserves of the same bed in northeastern Fulton County. In these areas this bed ranges from 3 ft 6 in. to 3 ft 9 in. in thickness. Where present elsewhere in the county, coal No. 6 is irregular in continuity and thickness. The available information indicates, however, that reserves in the north-central part of the county and in the southwestern corner of the county are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 outcrops widely throughout Knox County, but is generally less than 2 feet in thickness over most of the county, except along the southern boundary. In the latter area it ranges from 3 ft 0 in. to 3 ft 9 in. in thickness and has been worked by local underground operations and to some extent by larger stripping operations. The available information indicates that an area in the southwest corner of the county and a larger area in the southeast corner of the county are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply. The reserves of this bed in the southeastern portion of the county are adjacent to and contiguous with a larger area of reserves of the same bed in northeastern Fulton County.

Coal No. 2 underlies most of Knox County and outcrops irregularly along the sides of the deeper drainage systems. It has been opened along the outcrop by small operations in which the coal is found to vary from 1 ft 6 in. to 3 ft 0 in. in thickness. The available information is too limited in extent to permit estimates of reserves for this bed, but suggests that average thicknesses of the bed over large areas are too thin to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 1 occurs in a small, isolated area near the northwestern corner of Knox County. As in Henry County to the north, this bed is very irregular in occurrence, being confined to small elongated troughs of thick coal which thins rapidly toward the margins of the coal-bearing area. The available information indicates that reserves of this bed are too limited in amount to warrant further consideration.

LaSalle County. (See Exhibit No. 4 for references below) LaSalle County is located in the central portion of the northern margin of the coal-bearing formations in Illinois. Approximately the southern half of the county is underlain by coal-bearing strata. LaSalle County is crossed in a northwest-southeast direction in the west-central portion of the county by the LaSalle anticline. The coal beds west of the anticline occur in a deep trough from which the coal beds rise slowly toward the west and rapidly toward the east over the crest of the anticline. In the area east of the LaSalle anticline, the coal beds dip gently toward the southeast. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 140,000 tons were produced in LaSalle County in that year, of which 84,000 tons were obtained from two stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production of LaSalle County in that year was from the No. 2 bed.

The available information on coal occurrences in LaSalle County indicates that substantial reserves of coal No. 2 and relatively limited reserves of coal No. 6 are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 7 in LaSalle County was generally designated as the "First-Vein" bed. In the "Longwall District" west of the LaSalle anticline, this bed was largely left unmined during the extensive mining operations which took place in the underlying No. 2 bed in that area. The available information indicates that the No. 7 bed in the area west of the LaSalle anticline is too limited in extent to warrant further consideration in this survey.

Coal No. 6, formerly correlated as coal No. 5 of the Illinois series, was widely known as the "Second-Vein" coal in the "Longwall District" west of the LaSalle anticline. This bed was mined more extensively than the overlying No. 7 bed, but not to as great an extent as the underlying No. 2 bed in that area. The available information indicates that this bed was limited in extent and has been largely depleted. The apparent reserves are too limited in extent and too irregular in location to warrant further consideration as synthetic liquid fuels plant supply.

A thin bed, which has been tentatively correlated as coal No. 6, outcrops within a limited area along the banks of the Illinois River in the east-central portion of LaSalle County. The available information indicates that small areas of reserves at this location are sufficient for further consideration as synthetic liquid fuels plant supply.

Coal No. 2 underlies large areas east and west of the LaSalle anticline in southern LaSalle County. This bed was extensively mined in the so-called "Longwall District" which was formed by

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(References: 2, 13, 31, 33, 36)

the deep trough bordering the LaSalle anticline in the southwestern portion of the county. Mining operations were conducted at depths ranging up to approximately 600 feet. This coal approximated 3 ft 6 in. in average thickness, and large areas of reserves remain outside of the depleted areas which are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 2 in the area east of the LaSalle anticline on both sides of the Illinois River, is both thinner and inferior in quality to the No. 2 coal of the depleted "Longwall District". In this area the coal ranges from 2 ft 0 in. to 3 ft 5 in. in thickness, with the average approximating 2 ft 6 in. The available information indicates the presence of sufficient amounts of reserves of this coal in southeastern LaSalle County to warrant further consideration as synthetic liquid fuels plant supply. These reserves are adjacent to and contiguous with a large area of reserves of the same bed in western Grundy County.

Lawrence County. (See Exhibit No. 4 for references A below) Lawrence County is located in the southeastern portion of the Illinois coal field and is bordered on the east by the Wabash River which forms the State line at this location. Numerous oil tests in this county indicate that the southern axis of the LaSalle anticline extends along the western portion of Lawrence County, with the coal beds dipping away from the axis toward the west or east. No production has been reported in Lawrence County by either the Bureau of Mines or the Illinois Department of Mines and Minerals.

The available information on coal occurrences of Lawrence County indicates the presence of a small area of reserves extending into Lawrence County from Knox County, Ind. This area is a portion of a larger area in west-central Knox County, which has been relatively well determined by drilling. It is considered that the portion of these reserves extending into Lawrence County is a continuation of the Indiana No. 5 bed.

Numerous coal occurrences have been reported in the abundant oil tests distributed throughout Lawrence County. For the most part, these tests were not conducted in the presence of geologists of the Illinois Geological Survey and the recorded correlations and thicknesses of the coal beds are of doubtful utility. The available information is too limited in positive information to provide for the estimating of reserves.

Livingston County. (See Exhibit No. 4 for references B below) Livingston County is located in the northern part of the Illinois coal field. The LaSalle anticline extends through the western part of the county in a northwest-southeast direction. The general dip of the coal beds east of the LaSalle anticline is

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(References A: 25, 31, 33)
(References B: 2, 13, 31, 33)

toward the east with a reversal of dip toward the west on the opposite side of the anticline. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 5,000 tons were produced in Livingston County in that year from a single stripping operation. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the total production of Livingston County in that year was obtained in the northwestern corner of Livingston County near the town of Streator in southern LaSalle County from a bed which has been correlated with the Illinois No. 7 bed.

The available information on coal occurrences in Livingston County indicates the presence of relatively small reserves which, being adjacent to and contiguous with large reserves of No. 2 coal in southeastern Grundy County and northwestern Kankakee County, are considered suitable for further consideration as synthetic liquid fuels plant supply.

The No. 7 coal occurs in scattered areas in the northwestern portion of Livingston County south of the town of Streator, which is located in the southern part of LaSalle County. This bed has been extensively mined by both underground and stripping operations of relatively small size for local consumption, and for use in the ceramic industry in that area. The available information indicates that reserves of this bed have been largely depleted and that remaining reserves are too limited in extent and continuity to warrant further consideration in this survey.

An uncorrelated, channel-shaped coal deposit in which a maximum thickness of 12 ft 0 in. and an average thickness of 9 ft 0 in. have been recorded, occurs at a horizon approximately 10 feet above that of the No. 2 coal in northeastern Livingston County. The available information indicates that this bed is too limited in extent to warrant further consideration in this survey.

Coal No. 2 is considered to underlie a portion of the northeastern corner of Livingston County, largely by projection from known deposits in the adjacent counties in that area. Such information indicates that this coal ranges from 1 ft 6 in. to 2 ft 7 in. in thickness, and that a small area of reserves, which is contiguous with larger areas of reserves of the same bed in adjoining counties, is sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Large areas of Livingston County contain no information on underlying coal beds, although a bed tentatively correlated with the Illinois No. 5 bed has been shown by scattered drilling to occur near the western boundary of the county. The available information is too limited to permit any estimates of reserves.

Logan County. (See Exhibit No. 4 for references A below) Logan County is located in the west-central portion of the Illinois coal field. The general dip of the coal beds is toward the east. This county is largely covered with thick, surficial, glacial deposits, which have obscured the possible outcrops of any coal beds. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 50,000 tons were produced in Logan County in that year from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that this production was obtained from the No. 5 coal bed.

The available information on coal occurrences in Logan County indicates that substantial reserves of No. 5 coal are present in sufficient amount to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 underlies large portions of the southwestern quarter of Logan County. This bed has been mined south of the city of Lincoln, in the central part of the county. Extensive mining operations have also been conducted in northern Sangamon County, located south of Logan County. Coal No. 5 in Logan County varies from 4 ft 0 in. to 6 ft 0 in. in thickness, and is characterized by vertical shale partings which are commonly designated as "horsebacks". Where indicated to be present from underground operations and drill holes, the bed ranges from 230 to 350 feet in depth below the surface. The available information indicates the presence of sufficient reserves to warrant further consideration as synthetic liquid fuels plant supply. These reserves are adjacent to, and contiguous with, reserves of the same bed in eastern Menard County and in northern Sangamon County.

Macon County. (See Exhibit No. 4 for references B below) Macon County is located in the central portion of the Illinois coal field. The regional dip of the coal beds is toward the east. No production was reported from Macon County in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. The last reported production from this county, in annual reports of the Illinois Department of Mines and Minerals was in 1947, although it is reported that 11,000,000 tons have been produced from this county since 1882.

The available information on coal occurrences in Macon County indicates the presence of sufficient reserves of coal No. 5 to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 has been indicated by drill tests to underlie a small area in the southwestern corner of Macon County. This bed occurs in minable thickness south of a line through

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(References A: 6, 13, 31, 33, 36)
(References B: 6, 13, 31, 33, 36)

southern Sangamon, northern Christian, and southwestern Macon Counties, but the information in Macon County is too limited to permit estimates of reserves.

Coal No. 5 underlies the southwestern portion of Macon County at depths ranging from 350 to approximately 600 feet. This bed has been mined at the city of Decatur, located near the center of the county, and in the eastern portion of Sangamon County, located west of Macon County. The bed ranges from 4 ft 6 in. to 5 ft 6 in. in thickness, and is characterized by the vertical partings known as "horsebacks", which occur throughout the No. 5 coal area of central Illinois. The available information indicates that there are sufficient reserves of this coal to warrant further consideration for synthetic liquid fuels plant supply.

At least two other coal beds are known to occur below the No. 5 coal in Macon County. These have tentatively been correlated with the Illinois No. 2 and No. 1 beds. The available information is too limited, however, to permit estimates of reserves.

Macoupin County. (See Exhibit No. 4 for references below) Macoupin County is located in the southwestern portion of the Illinois coal field. The general dip of the coal beds is toward the east. The Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 4,281,000 tons were produced in Macoupin County in that year, entirely from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that total production in that year was obtained from coal No. 6.

The available information on coal occurrences in Macoupin County indicates the presence of sufficient reserves of coal No. 6 to warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 6 underlies the major portion of the county. It has been mined extensively in the eastern portion of the county, at depths of from 300 to 400 feet, and with thicknesses ranging from 6 ft 0 in. to 10 ft 0 in. The coal bed rises gently toward the west and becomes thinner and discontinuous in that direction. The available information indicates that the thickness of coal decreases to as little as 2 ft 0 in. near the western boundary of the county, and also shows the presence of scattered areas near the western boundary, where the coal bed has apparently been eroded. Irregular areas in the eastern and southeastern portions of Macoupin County represent a continuation of the large barren area which extends through Christian and western Montgomery Counties into eastern Madison County, which lies directly south of Macoupin County. This barren area represents a portion of the Illinois No. 6 coal basin in which the coal was either never deposited or was removed by erosion after deposition, with subsequent deposition of sandstone and

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(References: 7, 13, 22, 31, 33, 36)

shale at the original coal horizon. The available information on the No. 6 coal indicates that there are substantial reserves of this bed in the central portions of Macoupin County, which warrant further consideration in the production of synthetic liquid fuels.

Coal No. 5 has been found to underlie the No. 6 bed at irregular and scattered drill hole locations. These drill holes indicate that the thickness of the No. 5 bed ranges from 2 ft 0 in. to 3 ft 0 in. The available information is too limited in extent to permit further consideration of this bed as possible synthetic liquid fuels plant supply.

Madison County. (See Exhibit No. 4 for references below) Madison County is located in the southwestern portion of the Illinois coal field where it is bordered on the west by the Mississippi River. The general dip of the coal beds is toward the east, at an average rate of 13 feet per mile. The Bureau of Mines data on bituminous coal production for 1948, indicate that approximately 2,021,000 tons were produced in Madison County in that year, all of which was obtained from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production of Madison County in that year was from the No. 6 bed.

The available information on coal occurrences in Madison County indicates that there are substantial reserves of coal No. 6 which warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 6 outcrops along the Mississippi River bluffs on the western side of Madison County, and solidly underlies approximately the eastern three-fourths of the county. This bed ranges up to 8 ft 6 in. in thickness, and averages approximately 6 ft 0 in. in thickness in the central portion of the county, where it has been extensively mined. The barren area of Christian, Montgomery and Macoupin Counties extends southward into Madison County, along the eastern boundary line. Coal No. 6 was either never deposited in this barren area, or was eroded after deposition, followed by deposition of sandstone and shale at the original horizon of the bed. A possible extension of the above barren area, or a separate area of incomplete deposition, is also present in the southeastern corner of Madison County, where an area of thin coal is indicated to be present, from drill hole information. Other drill hole information suggests the possible presence of similar areas over substantial portions of the southeastern part of the county. Despite the presence of these areas of barren or thin coal, however, and although coal No. 6 has been widely depleted by underground operations in the central portion of the county, the remaining reserves are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

(References: 7, 13, 31, 33, 36)

Marion County. (See Exhibit No. 4 for references A below.) Marion County is located in the south-central portion of the Illinois coal field. The general dip of the coal beds is toward the east. The northern end of the Duquoin anticline extends in a north-south direction just west of the western line of Marion County, so that the deep beds east of the anticline in Marion County are relatively shallow in depth in eastern Clinton County. Bureau of Mines data on bituminous coal production in 1948, indicate that approximately 211,000 tons were produced in Marion County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in that year was from the No. 6 bed.

The available information on coal occurrences in Marion County indicates that there are sufficient reserves of the No. 6 coal in the southwestern portion of the county to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 underlies approximately the southwestern quarter of Marion County. Elsewhere within the county, the bed is indicated by scattered drilling to diminish in thickness and to become irregular in continuity and occurrence. In the southwestern portion of the county, the bed has been extensively mined at depths of approximately 550 feet with thicknesses averaging approximately 6 ft 0 in. The available information from abandoned mining operations and from drill holes in Marion County indicates that the No. 6 coal contains sufficient reserves to warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 5 has been indicated to underlie the No. 6 coal in at least one location in northeastern Marion County. The available information is too limited, however, to estimate the full extent of the reserves.

Marshall County. (See Exhibit No. 4 for references B below.) Marshall County is located in the northern portion of the Illinois coal field. The coal-bearing measures are approximately horizontal in the western part of the county, but have a slight easterly dip in the eastern portion. No production was reported from Marshall County in 1948 by the Bureau of Mines or by the Illinois Department of Mines and Minerals. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates a production of 80 tons from one local operation in this county for that year.

The available information on coal occurrences in Marshall County indicates that reserves of No. 7 coal west of the Illinois River in the western portion of Marshall County and reserves of No. 2 coal in the northeastern portion of the County, are sufficient

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(References A: 7, 20, 31, 33, 36)
(References B: 2, 31, 33, 36)

in extent to warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 7 has been mined by local operations near the eastern margin of Marshall County. This bed also occurs along the western banks of the Illinois River in the west-central portion of the county. In the latter area, bed thicknesses range from 3 ft 6 in. to 4 ft 0 in., with an average thickness of 3 ft 9 in. The information from abandoned mining operations in this bed in the eastern part of the county indicates that the bed is too irregular in thickness and continuity to warrant further consideration in this survey. West of the Illinois River, the available information indicates the presence of sufficient reserves of the No. 7 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 2 underlies substantial areas in the eastern portion of Marshall County where it has been extensively mined at depths of approximately 550 feet below the surface. The bed ranges in thickness from 2 ft 2 in. to 3 ft 9 in., with an average thickness of 3 ft 0 in. Although underground reserves of this bed in northeastern Marshall County have been depleted by underground operations, the remaining reserves are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

McLean County. (See Exhibit No. 4 for references below) McLean County is located in the north-central portion of the Illinois coal field and is largely underlain by thick, surficial, glacial deposits which mantle the bedrock information in this area. The general dip of the coal beds is toward the southeast. No production was reported from this county in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. The last reported production in annual reports of the Illinois Department of Mines and Minerals was in 1928, although it is reported that production from this county since 1882 has totaled 5,500,000 tons.

The available information on coal occurrences in McLean County indicates that relatively limited reserves of the No. 5 bed in the west-central portion of the county are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

A bed tentatively correlated as the Illinois No. 6 bed has been mined at one location in the northeastern portion of McLean County at a depth of approximately 400 feet. The thickness of this bed varied from 4 ft 0 in. to 6 ft 0 in. The available information, other than at the area of mining, is insufficient to permit the estimates of reserves.

(References: 6, 13, 31, 33)

Coal No. 5 has been mined near the central portion of the county, at the city of Bloomington. At this location, the bed averaged 3 ft 6 in. in thickness and was mined at a depth of 380 feet. The information available from this mine and from scattered drill-hole information is limited, and indicates that the bed is too irregular in thickness and continuity to estimate the full extent of the reserves.

The No. 2 bed was also mined in a limited manner from the same shaft at Bloomington which operated in the No. 5 bed, as described above. The depth of the No. 2 coal at this location was approximately 500 feet, with reported thicknesses ranging from 2 ft 11 in. to 3 ft 2 in. This information is insufficient to permit any estimates of reserves for the No. 2 coal.

Menard County. (See Exhibit No. 4 for references below.) Menard County is located in the west-central portion of the Illinois coal field. The general dip of the coal beds is toward the east. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 23,000 tons were produced from Menard County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from Menard County in that year was from the No. 5 bed.

The available information on coal occurrences in Menard County indicates that there are sufficient reserves of No. 5 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 solidly underlies the southeastern half of Menard County. This bed has been mined by underground operations in the southeastern portion of the county, at depths ranging from 100 to 200 feet below the surface. This coal averages 6 ft 0 in. in thickness and is characterized by the vertical "horsebacks" of shale or clay which are common in the No. 5 coal bed of central Illinois. The available information indicates that substantial reserves of the No. 5 coal remain in Menard County in sufficient amount to warrant further consideration as synthetic liquid fuels plant supply.

Other beds of coal, both above and below the No. 5 bed, have been indicated by shaft and drill-hole records. These beds are thin and the information is insufficient as to continuity and extent to permit any estimates of reserves.

(References: 6, 13, 31, 33, 36)

Montgomery County. (See Exhibit No. 4 for references below). Montgomery County is located in the southwestern portion of the Illinois coal field. The regional dip of the coal beds is toward the southeast, although the presence of minor local folds may modify the direction of dip in some locations. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 850,000 tons were produced in Montgomery County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from Montgomery County in that year was from the No. 6 bed.

The available information on coal occurrences in Montgomery County indicates that there are sufficient reserves of coal No. 6 and No. 5 to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 8 occurs largely as a horizon marker above coal No. 6 in the records of shafts and drill holes located within the county. This bed averages approximately 1 ft 0 in. in thickness and is too thin to warrant further consideration.

Coal No. 7 occurs at a vertical interval of approximately 30 feet above the No. 6 bed and averages approximately 2 ft 0 in. in thickness. The available information indicates that the bed is generally too thin to warrant further consideration in this survey.

Coal No. 6 has been mined in, and underlies most of, the southeastern half and a substantial area in the northwestern portion of Montgomery County. A large barren area separates these two portions of No. 6 coal reserves, in which the coal was either never deposited or was removed by erosion after deposition, with later deposition of sandstone and shale at the original coal horizon. This barren area extends into Christian County on the north and into Madison, Macoupin, and Bond Counties toward the southwest. The southeastern coal-bearing area is crossed by a relatively thin branch of the same barren area which extends in a southeasterly direction, with an average width of 1,000 feet, from approximately the center of Montgomery County to the southern county line.

The northwestern coal-bearing area of Montgomery County is contiguous with large areas of reserves of the same bed in southern Sangamon County and northern Macoupin County. No underground mining has been done in this area, but a large, new shaft operation has recently been installed. The southeastern coal-bearing area has been extensively mined by underground operations.

(References: 7, 13, 24, 26, 31, 33, 36)

Coal No. 6 in Montgomery County ranges from 3 ft 6 in. to 9 ft 8 in. in thickness, averaging approximately 7 ft 0 in. The available information indicates that there are sufficient remaining reserves in each coal-bearing area of Montgomery County to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 occurs at a vertical interval of from 30 to 60 feet below coal No. 6, with thicknesses varying from less than 2 ft 0 in. to a maximum of 5 ft 0 in. The available information indicates that there are relatively small areas of separated reserves of this bed in the northeastern, northwestern, and southwestern portions of Montgomery County. These are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

A coal bed tentatively correlated as the No. 2 bed has been worked by a relatively small shaft operation near the center of the southern line of Montgomery County, at a depth of approximately 700 feet below the surface and approximately 240 feet below the horizon of the No. 6 bed. This coal varied from 2 ft 2 in. to 7 ft 0 in. in thickness and was found to be irregular in continuity and thickness in the area depleted by the underground operation. The available information on this bed indicates that the coal is too limited in continuity to warrant further consideration.

Peoria County. (See Exhibit No. 4 for references below.) Peoria County is located in the northwestern portion of the Illinois coal field and is bounded on its southeastern side by the Illinois River. This county has been glaciated, and the outcrops of the bedrock in some areas are obscured by glacial deposits. The general dip of the coal beds is toward the southeast. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 641,000 tons were produced in Peoria County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from Peoria County in that year was obtained from the No. 5 bed.

Available information on coal occurrences in Peoria County indicates that there are substantial reserves of the No. 6 and the No. 5 beds which are sufficient in amount to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 7 occurs widely over the central and western portions of Peoria County where the bedrock formations are sufficiently high above drainage to contain this bed. The average thickness over most of the county is 1 ft 6 in., but the bed thickens

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(References: 6, 13, 14, 31, 33, 36)

...ually to a maximum of 3 ft 0 in. in portions of the northern part of the county. It has been opened along the outcrop in this latter area by small operations for local use. The available information indicates that this bed is generally too thin and too irregular in continuity to warrant further consideration in this survey.

Coal No. 6 or its horizon occurs widely over the western two-thirds of Peoria County. This bed varies greatly in thickness and in continuity, with large areas in the western portion of the county being marked only by a thin coal streak at the normal position of the No. 6 coal. In the central and north-central portions of the county, coal No. 6 is generally of minable thickness, ranging from 3 ft 3 in. to 4 ft 2 in. in thickness. Within this area, the upper 6 to 12 inches of the coal bed are frequently and irregularly replaced by downward projections from the coal bed roof. The available information indicates that sufficient reserves of the No. 6 bed are present, however, to warrant further consideration as synthetic liquid fuels plant supply.

The No. 5 bed occurs widely across the central and southeastern portions of the county. In the western portion of the county, a large, elongated area of this bed has apparently been displaced by channel-shaped sandstone deposits. Coal No. 5 has been extensively mined through drift or slope openings along the Illinois River in the southeastern portion of the county and by shaft operations in the highlands back of the river bluffs. In these areas, the bed ranges from 3 ft 0 in. to 4 ft 6 in. in thickness, averaging approximately 4 ft 0 in. As elsewhere in the No. 5 bed of central Illinois, vertical shale partings, designated as "horsebacks" interrupt the continuity of the coal bed at frequent intervals. These horsebacks range from a few inches to as much as 2 feet or more in width, and must be handled during the mining operation. The available information indicates that sufficient reserves of the No. 5 coal remain in Peoria County to warrant further consideration as synthetic liquid fuels plant supply.

The No. 2 bed occurs at a vertical interval of from 100 to 140 feet below coal No. 5 and has been mined by underground shaft operations along the Illinois River. In such operations this bed averaged 2 ft 6 in. in thickness. The bed apparently also outcrops below the river gravels in the Illinois Valley, composing the southern boundary of the county. The available information is insufficient to permit estimates of reserves for this bed.

Other coal horizons have been encountered at shaft and drill-hole locations and also outcrop within the boundaries of Peoria County. These beds apparently exist largely as horizon markers, with occasional local thickenings to a maximum of 3 ft 0 in. Available information indicates that these beds are too limited in thickness and continuity to warrant further consideration in this survey.

Perry County. (See Exhibit No. 4 for references below) Perry County is located in the southwestern portion of the Illinois coal field. The general dip of the coal beds over most of the county is toward the north and northeast. The axis of the Duquoin anticline extends in a north-south direction across the eastern portion of the county, near the eastern boundary line. The principal coal beds rise gently toward this anticline from approximately the central portion of Perry County and descend steeply toward the east from its crest. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 5,217,000 tons were produced from Perry County in that year, of which 2,799,000 tons were produced from three stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production in that year was from the No. 6 bed.

The available information on coal occurrences in Perry County indicates that there are sufficient reserves of the No. 6 and No. 5 coals to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 underlies large areas in Perry County and has been extensively mined both by stripping and underground operations. The outcrop of this bed roughly coincides with the western two-thirds of the southern boundary line, thence crosses into Jackson County in a southeast direction. Shaft operations have been conducted on the west side of the Duquoin anticline, with maximum depths of approximately 250 feet, while underground operations on the east side of the Duquoin anticline have been worked at depths averaging 450 feet. The thickness of the coal bed averages 6 ft 0 in. west of the Duquoin anticline and approximately 8 ft 0 in. on the east side. These differences in thicknesses are accompanied by marked differences in physical and chemical characteristics, with the seam on the east side of the anticline being of higher quality than that on the west. The available information indicates that substantial reserves of the No. 6 coal remain on the west side of the Duquoin anticline and are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 occurs in two separate areas in Perry County. In the southwestern portion of the county this bed is adjacent to, and contiguous with, reserves of the same bed in eastern Randolph County. In this area coal No. 5 ranges from 2 ft 0 in. to 6 ft 3 in. in thickness and has been mined near the outcrop by small local operations.

Coal No. 5 also occurs under relatively deep cover in the south eastern corner of Perry County where reserves in this bed are adjacent to, and contiguous with, larger areas of reserves of the same bed in northeastern Jackson County and in southwestern Franklin County. In this area, coal No. 5 averages approximately

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(References: 7, 15, 19, 21, 31, 33, 36)

4 ft 6 in. in thickness. This bed has been mined by both underground and strip operations in Jackson County, south of the area of reserves in southeastern Perry County. The available information indicates that sufficient reserves of the No. 5 coal are present in southeastern Perry County to warrant further consideration for the production of synthetic liquid fuels.

Putnam County. (See Exhibit No. 4 for references below) Putnam County is located in the north-central portion of the Illinois coal field and is partially bounded on its north side by the Illinois River. The regional dip of the coal beds is eastward toward the LaSalle anticline which crosses LaSalle County in a northwest-southeast direction east of the east line of Putnam County. No production is reported from Putnam County in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. The No. 2 bed, however, was formerly mined extensively in the northeastern portion of Putnam County, during the period of greatest activity in the "Longwall District" of northern Illinois, and it is reported that 10,000,000 tons were produced in the period of record subsequent to 1882.

The available information on coal occurrences in Putnam County indicates that sufficient reserves of coal No. 2 are present to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 7, also designated as the "First-Vein" bed of LaSalle County, occurs and has been locally mined by small shaft operations in the northeastern portion of Putnam County. Where mined, the thickness of this bed ranged from 2 ft 0 in. to 3 ft 6 in., and the bed was found to be irregular in continuity. The available information indicates that coal No. 7 is too irregular in continuity and too limited in extent to warrant further consideration in this survey.

Coal No. 6, the "Second-Vein" bed of LaSalle County, was also encountered in the shafts to the No. 2 bed in northeastern Putnam County. The thickness varied irregularly from 2 ft 0 in. to 4 ft 6 in. and the available information indicates that this bed is too limited in continuity and extent to warrant further consideration in this survey.

Coal No. 2 was once extensively worked in the northeastern portion of Putnam County, during the period of greatest activity in the so-called "Longwall District" of northern Illinois. In this area, coal No. 2 ranges from 3 ft 3 in. to 3 ft 6 in. in thickness and occurs at depths of approximately 450 feet below the surface. The bed appears to thin below 3 ft 0 in. to a minimum of 1 ft 0 in. in the southwestern portion of the county. The available information indicates that sufficient reserves of the No. 2 bed remain in northeastern Putnam County, where they are adjacent

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(References: 2, 6, 31, 33, 36)

to, and contiguous with, reserves of the same bed in west-central LaSalle County and southeastern Bureau County to warrant further consideration as synthetic liquid fuels plant supply.

Randolph County. (See Exhibit No. 4 for references A below) Randolph County is located in the southwestern portion of the Illinois coal field along the margin of the coal-bearing formations which comprise the Illinois coal basin. The general dip of the coal beds is toward the northeast. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 2,415,000 tons were produced in Randolph County in that year, of which approximately 1,063,000 tons were obtained from one stripping operation. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that all of the production in that year was obtained from the No. 6 bed.

The available information on coal occurrences in Randolph County indicates that there are sufficient reserves of coal No. 6 and No. 5 to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 outcrops in a northwest-southeast direction across the northeastern portion of Randolph County. This bed has been extensively depleted by both stripping and underground operations, the latter being confined largely to relatively shallow operations near the outcrop. The coal bed reaches a maximum depth of approximately 340 feet in the northeastern corner of Randolph County and ranges from 4 ft 6 in. to 7 ft 0 in. in thickness, averaging approximately 6 ft 0 in. While the No. 6 bed has been extensively depleted in Randolph County, the available information indicates that the remaining reserves are sufficient in extent to warrant further consideration as raw material for synthetic liquid fuels plant supply.

Coal No. 5 outcrops in a line southwest of, and parallel with, the outcrop of the No. 6 bed. The No. 5 bed varies from 1 ft 10 in. to 7 ft 0 in. in thickness along the outcrop, averaging approximately 3 ft 0 in., and has been mined by small local operations. The available information indicates that this bed is largely less than 2 ft 0 in. in thickness in the northern part of Randolph County, but that there are sufficient reserves of thicker coal in the northeastern portion of the county to warrant further consideration as synthetic liquid fuels plant supply.

Richland County. (See Exhibit No. 4 for references B below) Richland County is located in the southeastern portion of the Illinois coal field where the coal measures occur in the deeper part of the Illinois coal basin. The general dip of the coal beds

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(References A: 7, 15, 19, 31, 33, 36)
(References B: 25, 31, 33)

is toward the east. No production was reported from this county in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. A total of less than 200 tons has been reported as produced in Richland County since 1882, this production probably having been obtained from the thin surface seams which occur irregularly over portions of the county.

The only available information on the principal coal beds underlying Richland County has been obtained from oil tests made during the past 10 years. A limited number of such tests suggests that coal No. 6 and coal No. 5 may be present in portions of the county at depths ranging from 1,000 to 1,200 feet below the surface. From these oil tests and from the more numerous tests in Clay County west of Richland County, small areas of No. 5 and No. 6 coals are estimated to be present in the extreme northwest and southwest corners of the county. While other coal beds were penetrated by some of the oil tests, the available information is too limited to permit estimates of reserves.

Saline County (See Exhibit No. 4 for references below)
Saline County is located in the extreme southern portion of the Illinois coal field, along the southern outcrop of the principal coal-bearing formations of the Illinois coal basin. Coals No. 6 and No. 5 outcrop in a general east-west direction a short distance south of the center of the county. These beds dip toward the north at decreasing rates from the outcrop to the northern county line.

The southern portion of the coal-bearing area is marked by a relatively narrow, east-west zone of folding and faulting, with the faults commonly extending in a general northwest-southeast direction within this zone. The continuity of the coal beds is further disrupted by the presence of vertical dikes of igneous rock, which transect the coal bed at some locations, largely confined to the southeastern portion of the coal-bearing area. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 4,560,000 tons were produced in Saline County in that year, of which approximately 674,000 tons were produced from two stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 90 percent of the total production was obtained from the No. 5 bed, with 10 percent being obtained from bed No. 6.

The available information on coal occurrences in Saline County indicates that there are sufficient reserves of No. 6 and No. 5 coal to warrant further consideration as synthetic liquid fuels plant supply.

(References: 5, 12, 31, 33, 36)

Coal No. 6 solidly underlies the major coal-bearing area in the northern half of Saline County. This bed has not been extensively mined because of the greater thickness and higher quality of the underlying No. 5 bed, which has been widely worked in Saline County. The continuity of both beds is interrupted by the faulted and folded zone described above. Coal No. 6 ranges from 3 ft 0 in. to 7 ft 2 in. in thickness, but averages approximately 4 ft 6 in. It is approximately 600 feet in depth below the surface at the northern county line. While a large part of the southern portion of the No. 6 coal occurrence in Saline County has been undermined by operations in the underlying No. 5 bed, it is herein considered that these reserves could be recovered by carefully planned operations, and that such reserves, together with those remaining north of the No. 5 coal workings, are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 has been extensively mined across the center of Saline County, adjacent to, and north of, the outcrop of this bed. The continuity of this bed in the areas occupied by abandoned mines, and in the areas now undergoing active depletion, is known to be interrupted by faults and by dikes, as described above. In addition, the coal bed at some locations in the north-central part of the county has been partially or completely displaced by deposits of shale or sandstone. Coal No. 5 ranges from 3 ft 0 in. to 7 ft 6 in. in thickness, but averages approximately 6 ft 0 in. over large areas. Although the southern portion of the coal-bearing area of Saline County has been widely depleted, the available information indicates that substantial reserves remain in the northern portion of the county and are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Several coal beds, stratigraphically lower than the No. 5 bed, outcrop in an east-west direction across the southern portion of Saline County. These beds have been worked by small underground and stripping operations, but the available information is too limited to permit estimates of reserves.

In the southeastern corner of Saline County and separated from coal bed reserves to the north and west by a major fault, the western end of the Eagle Valley syncline, described under Gallatin County, contains small amounts of reserves in the Davis bed. The other coal beds within the Eagle Valley syncline in Saline County are too limited in extent to warrant further consideration in this survey.

Sangamon County. (See Exhibit No. 4 for references below) Sangamon County is located in the west-central portion of the Illinois coal field. The general dip of the coal beds is toward the

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(References: 6, 7, 31, 33, 36)

east. Two principal coal beds, the No. 5 and the No. 6 beds, are present in this county, with approximately the northern two-thirds being underlain by coal No. 5 and the southern one-third by coal No. 6. Coal No. 5 appears to become thin and irregular under the area underlain by coal No. 6, while coal No. 6 does not extend in workable thickness north of the approximate location of the south line of workable No. 5 coal. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 2,233,000 tons were produced in Sangamon County in that year, all of which was obtained from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from the county in that year was obtained from the No. 5 bed.

The available information on coal occurrences in Sangamon County indicates that there are substantial reserves of coal No. 6 and No. 5 which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 8 outcrops over extensive areas in Sangamon County, except along the eastern line where the regional dip carries this bed below drainage. Prior to development of the deeper No. 5 and No. 6 coals, this bed was mined along its outcrop by small, local operations. This coal ranges from 1 ft 6 in. to 2 ft 7 in. in thickness. The available information indicates that coal No. 8, except in small local areas, is too thin to warrant further consideration in this survey.

Coal No. 6 has been extensively mined in the south-central portion of Sangamon County at depths of from 240 to 300 feet. In this area, the bed ranges from 6 ft 0 in. to 8 ft 0 in. in thickness. The area of thick coal reserves extends eastward from the depleted area toward northern Christian County, but the bed thins rapidly and becomes unworkable elsewhere within the county. The available information indicates that there are substantial reserves of this bed which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 has been widely mined in and around the city of Springfield which is located in the north-central part of Sangamon County. This bed solidly underlies the northern two-thirds of Sangamon County, where it averages approximately 5 ft 6 in. in thickness. Over most of its area of occurrence, the bed is persistent in thickness but decreases to less than 2 ft 0 in. toward the south and southwest. Coal No. 5 is characterized throughout central Illinois by frequent vertical partings of shale or clay, ranging in width from a few inches to 2 feet or more, which are designated as "horsebacks". These impurities in the coal must be handled during the mining operation. Although widely depleted in the north-central portion of the county, in and around the city of Springfield, the available information indicates that the remaining reserves are substantial and warrant further consideration as synthetic liquid fuels plant supply.

Schuyler County. (See Exhibit No. 4 for references A below) Schuyler County is located in the southern portion of the northwestern part of the Illinois coal field, west and northwest of the Illinois River. The basal coal beds in this area are shallow in depth, and local stream erosion has produced a narrow cutout of the coal measures, extending in a northwest-southeast direction across the western portion of Schuyler County. The general dip of the coal beds is toward the southeast. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 140,000 tons were produced in Schuyler County in that year, of which 128,000 tons were produced from one stripping operation. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 80 percent of the production in that year was obtained from coal No. 5, with approximately 20 percent being produced from coal No. 2.

The available information on coal occurrences in Schuyler County indicates that there are sufficient reserves of No. 5 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 underlies a relatively small ridge formed of resistant bedrock material in the central portion of the county. This occurrence of No. 5 coal is completely detached from the major No. 5 coal areas in the Springfield and Fulton-Peoria districts. This area of reserves has been thoroughly drilled and prospected and is now undergoing depletion by a stripping operation. The bed ranges from 2 ft 4 in. to 6 ft 0 in. in thickness, with an average thickness of approximately 5 ft 0 in. The vertical "horsebacks", characteristic of the No. 5 coal elsewhere in the State, are relatively infrequent in occurrence in Schuyler County. The available information indicates that reserves of this bed are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 2 occurs widely over the two coal-bearing areas of Schuyler County, east and west of the cutout described above. This bed has been worked along its outcrop at a number of locations by small local operations. Although usually less than 2 ft 0 in. in thickness, the bed locally attains a maximum thickness of 3 ft 0 in. The available information is insufficient to establish estimates of reserves, but suggests that the thickness is less than 2 ft 0 in. over large areas.

Shelby County. (See Exhibit No. 4 for references B below) Shelby County is located in the south-central portion of the Illinois coal field. The coal-bearing strata in the eastern part of this county occur along the deep trough which parallels the LaSalle anticline, and the general dip of the coal beds in this

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(References:A: 10, 13, 31, 33)
(References B: 7, 26, 31, 33, 36)

portion of the county is toward the west. On the west side of the county the beds dip eastward into the trough. No production was reported from Shelby County in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. Limited and scattered production has been reported from Shelby County in previous years, this being obtained from irregular, shallow beds which outcrop near the surface in the eastern part of the county.

The available information on coal occurrences in Shelby County indicates that there are sufficient reserves of No. 5 and No. 6 coal in the western portion of the county to warrant further consideration as synthetic liquid fuels plant supply.

The shallow coal from which limited amounts of production have been obtained in prior years in eastern Shelby County has been designated as the "Shelbyville" coal and tentatively correlated as coal No. 14 by the Illinois Geological Survey. The available information is limited but indicates that this bed is too limited in extent, thickness, and continuity to warrant further consideration in this report.

Coal No. 6 underlies a substantial part of the southwestern portion of Shelby County. This bed has been worked in the southeastern corner of Christian County just west of the west line of Shelby County, at depths of approximately 700 feet. The information provided by such operations and by scattered drill holes indicates that the No. 6 coal in Shelby County ranges from 5 ft 0 in. to 7 ft 7 in. in thickness. A large portion of the central part of Shelby County is probably connected with the large barren area which extends through Christian, Montgomery, Macoupin, Madison, and Bond Counties. Limited information indicates that coal No. 6 is present north of the barren area, in the northwestern corner of Shelby County, but is insufficient to provide a basis for estimates of reserves. The available information indicates that there are sufficient reserves of the No. 6 bed in southwestern Shelby County to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 extends a short distance into northwestern Shelby County from the large area underlain by this bed in southwestern Macon County, eastern Sangamon County, and northern Christian County. The available information indicates that this bed occurs at depths of approximately 600 to 800 feet in Shelby County, with thicknesses ranging from 5 ft 4 in. to 7 ft 0 in. The reserves of this bed in northwestern Shelby County are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Stark County. (See Exhibit No. 4 for references A below) Stark County is located in the central portion of the northwestern part of the Illinois coal field, lying northwest of the Illinois River. The general dip of the coal beds is toward the southeast. No production was reported from Stark County in 1948 by the Bureau of Mines or by the Illinois Department of Mines and Minerals. Annual records of the latter Department indicate that approximately 1,200,000 tons have been produced in Stark County during the period of record from 1882 to 1948. Such production was probably obtained from the No. 6 bed.

The available information on coal occurrences in Stark County indicates that there are sufficient reserves of the No. 6 bed to warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 6, or its horizon, outcrops widely across the southeastern portion and central portion of Stark County and underlies substantial areas in the northern portion of the county. While the horizon of No. 6 coal is persistent in Stark County, large areas along the outcrop contain coal of but a few inches in thickness. In the north-central portion of the county, coal No. 6 is more persistent, ranging from 3 ft 9 in. to 4 ft 2 in. in thickness over relatively large areas. Even in such areas of thicker coal, however, the upper 6 to 12 inches of the bed may be irregularly and frequently displaced by downward projections of material from the coal bed roof, and the bed is commonly high in inherent ash. The available information indicates that there are sufficient reserves to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 outcrops along the southern line of the county but is generally less than 2 ft 0 in. in thickness. The available information indicates that this bed is too thin to warrant further consideration in Stark County.

St. Clair County. (See Exhibit No. 4 for references B below) St. Clair County is located in the southwestern portion of the Illinois coal field and occupies a position along the margin of the coal-bearing formations which comprise the Illinois coal basin. This county is bordered on the west by the Mississippi River. Located directly across the Mississippi River from the city of St. Louis, its geographic position has been an important factor in the development of the coal beds in this county. The general dip of the coal beds is toward the east, although local and minor folding may modify this direction of dip in some locations. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 3,021,000 tons were produced in this county in that

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(References A: 2, 4, 13, 31, 33, 36)
(References B: 7, 13, 31, 33, 36)

year, of which 1,029,000 tons were obtained from three stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production of the county in that year was obtained from the No. 6 coal.

The available information on coal occurrences in St. Clair County indicates that extensive reserves of the No. 6 bed and relatively small reserves of the No. 5 bed warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 underlies approximately the eastern three-fourths of the county. The actual outcrop across the southwestern portion of the county is largely obscured by glacial deposits. The outcrop is visible along the eastern bluffs of the Mississippi River and has been utilized for extensive drift mining. The bed has also been mined intensively throughout the western and southwestern portions of the coal-bearing area. This extensive depletion has been accomplished by underground operations up to 400 feet in depth and by stripping operations at favorable locations along the outcrop. Coal No. 6 ranges in thickness from 4 ft 0 in. to 8 ft 3 in. Although extensively depleted, the available information indicates that there are substantial reserves remaining in eastern St. Clair County which warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 occurs in a limited area in the central part of St. Clair County. In this area, the coal ranges from 3 ft 0 in. to 3 ft 2 in. in thickness and has been mined in local areas of up to 5 ft 0 in. in thickness. Elsewhere within the county the outcrop of the No. 5 bed has not been extensively explored, but the limited available information indicates that it is generally too thin to warrant further consideration.

Tazewell County. (See Exhibit No. 4 for references below) Tazewell County is located in the northwestern portion of the Illinois coal field. This county is bordered on the northwest by the Illinois River. The general dip of the coal beds is toward the east. The eastern portion of the county has been heavily glaciated, so that rock outcrops are largely obscured. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 73,000 tons were produced in Tazewell County in that year, all by underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production from Tazewell County in that year was obtained from the No. 5 bed.

The available information on coal occurrences in Tazewell County indicates that there are sufficient reserves of the No. 5 bed to warrant further consideration as synthetic liquid fuels plant supply.

(References: 6, 31, 33, 36)

Coal No. 6 outcrops along the Illinois River bluffs, in west-central Tazewell County, and in the tributaries draining toward the Illinois River. As in Peoria County, west of the Illinois River, the No. 6 bed is extremely irregular in continuity and occurrence with thicknesses varying abruptly within short distances from less than 1 ft 6 in. to as much as 4 ft 0 in. The upper portion of the coal bed is frequently replaced with material from the overlying formation. The available information indicates that reserves of No. 6 coal in Tazewell County are too irregular in occurrence and continuity to warrant further consideration in this survey.

Coal No. 5 outcrops along the Illinois River Valley and has been mined by shallow, underground operations in this area. Where indicated by underground operations and by outcrops, the thickness of the No. 5 bed ranges from 4 ft 4 in. to 4 ft 10 in. As in Peoria County, across the Illinois River from Tazewell County, No. 5 coal is characterized by vertical partings known as "horsebacks". Large areas in Tazewell County have not been explored by underground operations or by drilling to the No. 5 coal horizon. It is possible that the heavy glaciation has removed the No. 5 bed in areas in which the topography is such that the bed should normally be present. The available information, however, indicates that there are sufficient reserves adjacent to the developed area in west-central Tazewell County to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 2 is probably present below the Illinois River valley gravels in at least portions of Tazewell County. The information concerning this bed, however, is insufficient for any estimates of reserves.

Vermilion County. (See Exhibit No. 4 for references below) Vermilion County is located in the north-central portion of the eastern Illinois coal-containing counties where it is both geographically and geologically separated from the other principal coal-producing districts in Illinois, probably being more closely connected with the coal-bearing formations of southwestern Indiana than with the other portions of the Illinois coal basin. The coal beds in Vermilion County, however, have been correlated as closely as possible with the principal coal beds in the other portions of the Illinois coal field by the Illinois State Geological Survey. The general dip of the coal beds is toward the southwest. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 359,000 tons were produced in Vermilion County in that year, of which 91,000 tons were obtained from two stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the majority of the coal produced in Vermilion County in that year was obtained from the No. 7 bed,

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(References: 3, 31, 33, 36)

with but minor amounts being obtained from the No. 6 bed. In previous years, however, during which mining operations in Vermilion County were considerably more extensive than at present, the principal producing bed was the No. 6 bed.

The available information on coal occurrences in Vermilion County indicates that there are sufficient reserves of coals No. 7 and No. 6 to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 7 underlies large portions of south-central Vermilion County, where it is frequently designated as the "Danville" bed by reason of the mining activities which have been concentrated near the city of Danville, located in the east-central portion of the county. This bed ranges from 2 ft 4 in. to 7 ft 0 in. in thickness and is generally persistent throughout its area of occurrence, although it tends to become thin and irregular toward the western and southern county lines. While this bed has been extensively mined by both underground and stripping operations, there are extensive reserves, much of which occur in areas where the underlying No. 6 bed has been depleted. It is herein considered, however, that such reserves can be recovered by carefully planned operations, and the available information indicates that there are sufficient reserves remaining in Vermilion County to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 underlies large portions of southern Vermilion County. This bed is locally designated as the "Grape Creek" bed, but has been correlated as occurring at the approximate vertical position occupied by the main No. 6 bed in the remainder of the Illinois coal basin. Coal No. 6 in Vermilion County has been extensively mined by underground operations, at depths ranging from less than 100 to over 200 feet. This bed ranges from 2 ft 0 in. near the margins of the area of occurrence, to as much as 10 ft 0 in. in thickness in some areas of local thickening. While extensively depleted, the available information indicates that there are sufficient remaining reserves in the No. 6 bed in Vermilion County to warrant further consideration as synthetic liquid fuels plant supply.

Other thin beds, stratigraphically lower than the No. 6 bed, outcrop near the Indiana State line and have been opened for local consumption. The available information on these coal occurrences is insufficient to permit estimates of reserves. Coal beds stratigraphically higher than the No. 7 coal outcrop near the western county line, but the available information indicates that these are too thin to warrant further consideration.

Wabash County. (See Exhibit No. 4 for references A below) Wabash County is located in the southeastern portion of the Illinois coal field and is bordered on the southeast by the Wabash River. The general dip of the coal beds is toward the west. No production was reported from this county in 1948 by the Bureau of Mines or the Illinois Department of Mines and Minerals. The annual records provided by the latter source indicate that relatively small amounts of coal have been produced intermittently in Wabash County during the years subsequent to 1882. Such production was probably obtained from thin, irregular beds which outcrop at scattered locations within the county.

The shallow coals of Wabash County are located in scattered areas along the Wabash River and in the east-central portion of the county, west of the river bluffs. These coals are stratigraphically high in the coal-bearing formations and cannot be correlated with the principal coal beds of the Illinois coal basin. While these beds have been locally operated over many years by small underground operations, the available information indicates that these beds are generally too thin and discontinuous in occurrence to warrant further consideration.

The available information on the principal coal beds of the Illinois coal basin in Wabash County are restricted to oil-test records, which have been put down in large numbers in the last ten years. The drilling results further indicate that the coal-bearing formations underlying Wabash County are probably interrupted by a number of faults of varying magnitude. While several deep coal beds have been encountered in such oil testing, their correlation and continuity cannot be demonstrated by the available data. A small area of coal reserves in north-central Wabash County, tentatively correlated with the No. 5 bed, has been estimated to be present from data provided by oil tests which were examined during drilling by representatives of the Illinois State Geological Survey.

Washington County. (See Exhibit No. 4 for references B below) Washington County is located in the southwestern portion of the Illinois coal field. The general dip of the coal beds for most of the county is toward the northeast. The axis of the Duquoin anticline extends in a north-south direction across the eastern portion of the county, closely adjacent to the eastern county line. The beds rise slowly toward the crest of the Duquoin anticline, from approximately the center of Washington County, then descend sharply to deeper elevations east of the axis of the anticline. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 495,000 tons were produced in Washington County in that year, all from underground operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that the entire production of the county for that year was from the No. 6 bed.

(References A: 25, 31, 33)
(References B: 7, 19, 21, 31, 33, 36)

The available information on coal occurrences in Washington County indicates that substantial reserves of the No. 6 bed and relatively small reserves of the No. 5 bed are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal beds stratigraphically higher than the Illinois No. 6 bed have been reported in shafts and drill-hole records, which have been put down to the No. 6 bed. These coal beds are generally thin, and the available information indicates that they are too thin and irregular to warrant further consideration in this survey.

Coal No. 6 underlies large portions of the southern part of Washington County. This bed has been depleted by underground operations, largely confined to the western and southwestern portions of the county. Underground mining operations have also been developed by relatively small mines located in the center of the county and along the eastern county line.

The available information is insufficient to show whether an extension of the barren area in southeastern Madison and western Clinton Counties projects into northwestern Washington County. Where present, coal No. 6 ranges from 5 ft 0 in. to 9 ft 4 in. in thickness and averages around 6 ft 0 in. over most of the area of occurrence. The available information indicates that the remaining coal reserves of No. 6 bed in Washington County are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 has been indicated to occur in a small area near the central part of the county, where it has been encountered in drill holes extending below the No. 6 bed. In this area, the No. 5 coal ranges from 4 ft 0 in. to 6 ft 6 in. in thickness, and the reserves are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply. The drill-hole information in other portions of Washington County is too meager to permit any estimates of reserves.

Wayne County. (See Exhibit No. 4 for references below) Wayne County is located in the southeastern portion of the Illinois coal field, where the coal measures occur near the deepest portions of the Illinois coal basin. The general dip of the coal-bearing formations is toward the east and northeast. No production has been reported from Wayne County by the Bureau of Mines or the Illinois Department of Mines and Minerals.

The available information on coal occurrences in Wayne County is confined to numerous oil tests, which have been put down

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(References: 7, 13, 31, 33)

within the county boundaries during the past ten years. Many of these tests were attended by representatives of the Illinois State Geological Survey, who examined the data on depth and thickness of coal beds encountered during the drilling. The available information from such oil tests indicates that at least two coals, tentatively correlated with the Illinois No. 6 and No. 5 beds, underlie large portions of Wayne County, at depths ranging from 900 to approximately 1,200 feet below the surface. While sufficient to indicate the presence of substantial coal reserves, these drill tests do not reveal the character and quality of the coal or the physical characteristics of the roof, coal bed, and floor. The available information, however, is sufficient to indicate the present of substantial areas of reserves of both No. 5 and No. 6 coals in Wayne County, which warrant further consideration as synthetic liquid fuels plant supply.

White County. (See Exhibit No. 4 for references below) White County is located in the southeastern portion of the Illinois coal field and is bounded on the east by the Wabash River. The coal-bearing formations underlying this county are located in the deepest part of the Illinois coal trough. The general dip of the coal-bearing strata is toward the northeast. No production was reported from this county in 1948 by the Bureau of Mines. The last reported production from White County in annual reports of the Illinois Department of Mines and Minerals was in 1948, although a total production of over 1,600,000 tons has been recorded since 1882.

The available information on coal occurrences in White County indicates that there are substantial reserves of the No. 6 and the No. 5 coals in the southwestern portion of the county, which are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 has been mined at a relatively small shaft operation near the town of Norris City, in the southwestern part of White County, at a depth of 635 feet below the surface. At this location the coal bed was 5 ft 6 in. in thickness. Limited drill-hole information elsewhere in the county indicates that minable reserves are largely confined to the southwestern portion of the county. Elsewhere, as revealed by numerous oil tests which have been put down in the last ten years, both the No. 6 and the underlying No. 5 coal are considered to occur erratically because of the apparent presence of numerous northeast-southwest faults, which appear to pass across the eastern and northern portions of the county. In southwestern White County, the No. 6 bed reserves adjoin and are contiguous with larger areas of reserves of the same bed in Gallatin County on the south, and Saline County on the southwest, and Hamilton County on the west. The available information indicates that the reserves

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(References: 7, 13, 18, 31, 33, 36)

of the No. 6 coal in this area are sufficient to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 5 was also mined in the shaft operation located in the town of Norris City. With the information provided by this shaft and by scattered drill holes, it is indicated that the No. 5 bed underlies relatively minor areas located along the southern line and in the southwest portion of White County at depths ranging from 570 to 970 feet below the surface. Within this area, the bed appears to range from 4 ft 0 in. to 6 ft 0 in. in thickness. The reserves in this location adjoin larger reserves of the same bed in northern Gallatin County and in northeastern Saline County. As with the overlying No. 6 coal, the No. 5 bed appears to be irregular in structure in the eastern and northern portions of White County because of the presence of northeast-southwest faults which intersect the coal-bearing formations in these locations. The available information indicates that there are sufficient reserves of the No. 5 coal in southwestern White County to warrant further consideration as synthetic liquid fuels plant supply.

Will County. (See Exhibit No. 4 for references below) Will County is located in the northeast portion of the Illinois coal field, along the margin of the coal-bearing formations. The general dip of the coal beds is toward the south and west. In the Bureau of Mines report on bituminous coal production for 1948, the production from Will County is combined with production from Grundy County, which is located directly west of Will County. The reported production for the two counties was 1,835,000 tons, which were entirely obtained from four stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 1,650,000 tons were produced in Will County in that year, largely from the No. 2 bed, with a relatively small amount from the No. 7 bed.

The available information on coal occurrences in Will County indicates that there are substantial reserves of coal No. 2 which warrant further consideration for synthetic liquid fuels plant supply.

Coal No. 7 outcrops in, and underlies a small area in the extreme southwestern corner of Will County, where it is being stripped at a local operation. The available information indicates that this bed is too limited in continuity and extent to warrant further consideration in this survey.

Coal No. 2 outcrops in a northwest-southeast direction across the southwest corner of Will County, swinging almost directly south at the southern county line. This bed at one time

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(References: 2, 13, 31, 33, 36)

was extensively mined by underground operations ranging up to 150 feet in depth. Except for small local underground operations, however, the bed is now largely being mined by stripping in areas adjacent to the outcrop. The No. 2 bed ranges from 2 ft 3 in. to 3 ft 0 in. in thickness in Will County. The available information indicates that reserves of the No. 2 bed in southwestern Will County, where they are adjacent to, and contiguous with, larger reserves of the same bed in southeastern Grundy County and northwestern Kankakee County, are sufficient in extent to warrant further consideration for synthetic liquid fuels plant supply.

Williamson County. (See Exhibit No. 4 for references below) Williamson County is located in the southern portion of the Illinois coal field, near the southern margin of the coal-bearing formation. The coal-bearing strata outcrop in an east-west direction, across Williamson County, with the general dip of the coal beds being toward the north over most of the area. The principal coal beds in the northeastern portion of Williamson County rise in an easterly direction, however, toward the crest of the Duquoin anticline, which extends in a north-south direction along the eastern boundary of Jackson County, immediately west of the west line of Williamson County. The coal beds in Williamson County have also been affected by the structural displacements occurring in an east-west trending zone near the southern outcrops of the beds. Within this zone the coal beds are folded and cut by faults which have a general northwest-southeast direction. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 4,920,000 tons were obtained from this county in that year, of which approximately 1,268,000 tons were obtained from mine stripping operations. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that approximately 80 percent of the total production in Williamson County in that year was obtained from the No. 6 bed, with 20 percent being obtained from bed No. 5.

The available information on coal occurrences in Williamson County indicates that there are sufficient reserves of No. 6 and No. 5 coal to warrant further consideration as synthetic liquid fuels plant supply.

Coal No. 6 outcrops in a slightly northwest-southeast direction across the northern half of Williamson County. This bed has been widely depleted, especially in the western half of its area of occurrence, by stripping operations and by underground operations ranging up to approximately 400 feet in depth. The coal bed ranges from 3 ft 9 in. to 8 ft 0 in. in thickness. The available information indicates that substantial reserves of No. 6 coal remain in the northeastern corner of Williamson County and are sufficient in extent to warrant further consideration as synthetic liquid fuels plant supply.

(References: 4, 20, 31, 33, 35, 36)

Coal No. 5 outcrops in a parallel line a short distance south of the outcrop of the No. 6 bed. This bed has been depleted by both stripping and underground operations along the eastern county line where the characteristics of No. 5 coal are similar to the characteristics of the same bed in Saline County to the east. Toward the west, coal No. 5 decreases in thickness and has been mined but locally by small operations near the outcrop. Although somewhat depleted by relatively small operations, the available information indicates that there are sufficient reserves in the northeastern portion of Williamson County, where they adjoin and are contiguous with reserves of the same bed in Saline County, to warrant further consideration as synthetic liquid fuels supply. The available information also indicates that there are sufficient reserves of the No. 5 coal in northwestern Williamson, where they are adjacent to, and contiguous with, reserves of the same bed in southwestern Franklin County and in northeastern Jackson County, to warrant further consideration as synthetic liquid fuels plant supply.

Several coals stratigraphically lower than the No. 5 bed outcrop in a general east-west direction across the southern portion of Williamson County. These beds have been opened for local use at irregular locations along their outcrops. The available information indicates that these beds are generally thin or irregular in thickness, and too limited to provide estimates of coal reserves for these beds.

Estimated Percentage of Recovery of Coal in Place

Broad over-all records of percentage of recovery from coal reserves in place in existing underground and strip mine operations in Illinois are not available. In 1923 the Bureau of Mines prepared a summary report on "Amount and Nature of Losses in Mining Bituminous Coal in Eastern United States", which was published in 1925 as a portion of the report of the United States Coal Commission, established in accordance with Public Act No. 347 by Congress on September 22, 1922. This report, which covered only the underground mining which prevailed at that time, found that in 1921 the average amount of coal lost in individual mining operations in Illinois was 49 percent, indicating a recovery of 51 percent.

In estimating percentage of recovery from reserves in place across broad areas, such as those established in this report, the amount of over-all bed losses entailed in future mining operations would normally be considered as exceeding the average percent of losses involved in individual operations, assuming that methods of mining were not essentially changed. The causes of such decreases in over-all recovery in broad areas include coal left in barrier pillars between mines, coal left in mined-over areas when

individual active operations are abandoned, coal unmined because of undetected local decreases in thickness, quality, or continuity, coal left in place under towns, cemeteries, railroads, schools, or other reservations, coal left in pillars around oil and gas wells, etc. The percentage of recovery from coal reserves in place by underground mining in this report, based upon available data, and on providing for possible contingencies cited above, is estimated as 50 percent.

Although individual stripping operations recover a materially higher percentage of the original coal in place than underground operations, the estimating of over-all recovery of strippable reserves over substantial areas requires consideration of the bearing of a number of economic factors on final percent of recovery. These factors include allowances for areas which probably will not be stripped because of the presence of town developments, improved highways, existing facilities of all kinds, and because of possible excessive costs of acquisition, local decreases in thickness, quality or continuity of the coal bed, etc. In many areas of Illinois a portion of some individual coal beds adjacent to and parallel with, extensive lengths of outcrop has been weathered to such an extent that the coal is soft and dirty, thus becoming unavailable for mining. In order to provide for possible contingencies thus indicated, the percentage of recovery by stripping operations in this report is estimated as 60 percent.

Summary Description of Estimated Coal Reserves

The total tonnage of coal considered available for synthetic liquid fuels manufacture in Illinois as at January 1, 1950, based on available information and within the limits of reserves specified for this survey as described in Part II of this report under "Definitions" and in Part IV under "Survey Methods and Procedure" was estimated at 49,633,725,000 tons in place. Of this amount 24,867,174,000 tons were estimated as being recoverable. Because of the limitations imposed by this survey the estimates presented herein are not comparable with other coal estimates which generally include the total coal reserves in Illinois. For example, in Circular 94 of the U.S. Geological Survey, the total recoverable reserves for Illinois, as of January 1, 1950 (assuming 50 percent recovery), are reported to be 82,820,503,000 tons. This estimate of the Geological Survey adopts a 1946 estimate by Cady, in turn for the most part based on estimates of Cady, Culver, Kay, and White, published in 1925 or earlier.

The detailed data on coal reserves estimated in the synthetic liquid fuels survey, were presented in a volume of Coal Data Sheets which are available for examination at certain depositories listed in Exhibit No. 5. The recoverable coal reserves are also indicated on the coal data sheets and summarized by counties and beds in Exhibit No. 7. The estimated total recoverable reserves (24,867,174,000 tons) are recapitulated by counties and beds in the table which follows. Diagrammatic outlines of the areas underlain by reserves of the several coal beds are indicated on Exhibit No. 8.

As shown in the following table, seven coal beds were found to contain suitable reserves for production of synthetic liquid fuels, according to the definitions and procedures established for this survey. The No. 6 bed contains over 17,200,000,000 tons of estimated recoverable reserves, with these reserves being located in 37 of the 53 counties selected as suitable for consideration (fifth column of table). The greatest concentrations of No. 6 coal reserves are in Montgomery, Macoupin, Bond, and Clinton Counties in central Illinois and in Jefferson, Franklin, and Hamilton Counties in southern Illinois. Coal No. 5 contains approximately 6,800,000,000 tons, these reserves being located in 38 of the 53 counties for which reserves were estimated. The greatest concentrations of No. 5 coal reserves are in central and southeastern Illinois. Total reserves of the No. 2 bed approximate 569,000,000 tons, with their greatest concentration being in Grundy and LaSalle Counties, along the Illinois River. Coal No. 7 reserves are relatively limited in amount, occurring largely in Vermilion County. Limited reserves in the Davis and Willis beds occur in the Eagle Valley field.

With estimated reserves in each of the No. 5 and No. 6 beds, the largest amount of reserves in a single county occurs in Sangamon County where it totals approximately 1,800,000,000 tons. Ten additional counties each contain over one billion tons of reserves, these being Montgomery, Hamilton, Christian, Macoupin, Clinton, Franklin, Saline, Perry, Bond and Jefferson Counties. The reserves in the remaining 42 counties range from approximately 935,000,000 tons in St. Clair County to 1,250,000 tons in Jasper County. In the latter case, these reserves, in bed No. 5, are adjacent to and contiguous with a larger area of reserves of the same bed in northern Clay County.

Estimated Total Recoverable Reserves in Illinois Considered for Synthetic Liquid Fuels Manufacture by Counties and Beds (A) (Thousands of Tons)
(As of January 1, 1950)

County	Coal Bed					
	Davis & Willis	No. 2	No. 5	No. 6	No. 7	Total
Will		2,027				2,027
Grundy		171,804				171,804
LaSalle		160,732		7,690		168,422
Bureau		49,866		49,419		99,285
Henry		7,817		98,760		106,577
Putnam		83,248				83,248
Kankakee		26,688				26,688
Livingston		5,322				5,322
Marshall		61,139			36,269	97,408
Stark				69,555		69,555
Knox			60,439	116,453		176,892
Peoria			268,572	184,504		453,076
McLean			4,392			4,392
Tazewell			39,340			39,340
Fulton		236,511		12,682		249,193
Vermilion				134,551	225,868	360,419
Logan		442,280				442,280
Schuyler		56,352				56,352
Menard		457,033				457,033
Macon		258,120				258,120
Sangamon		1,266,814		532,590		1,799,404
Christian		597,199		802,618		1,399,817
Shelby		36,985		492,086		529,071
Edgar		207,749(D)				207,749
Montgomery		49,938		1,536,866		1,586,804
Macoupin				1,366,895		1,366,895
Greene				6,849		6,849
Jersey				19,569		19,569
Jasper		1,250				1,250
Effingham		6,139		1,382		7,521
Fayette		5,941		854,626		860,567
Bond		2,543		1,046,026		1,048,569
Madison				681,450		681,450
Lawrence		4,801(D)				4,801
Richland		1,892		52		1,944
Clay		229,135		145,800		374,935
Marion		923		139,100		140,023
Clinton		6,110		1,291,965		1,298,075
St. Clair		16,250		919,120		935,370
Wabash		12,443				12,443
Edwards		1,584		1,815		3,399
Wayne		527,993		394,196		922,189
Jefferson		12,766		1,009,169		1,021,935
Washington		12,689		679,239		691,928
White		105,613		191,220		296,833
Hamilton		432,450		1,040,692		1,473,142
Franklin		103,114		1,015,719		1,118,833

Estimated Total Recoverable Reserves in Illinois Considered for Synthetic Liquid Fuels Manufacture by Counties and Beds (A) (Thousands of Tons)
(As of January 1, 1950)
(Concluded)

County	Coal Beds					
	Davis & Willis	No. 2	No. 5	No. 6	No. 7	Total
Perry			114,956	955,145		1,070,101
Randolph			119,508	205,611		325,119
Gallatin	5,817(B)		238,375	322,287		566,479
Saline	1,728(C)		435,240	681,368		1,118,336
Williamson			323,108	222,131		545,239
Jackson			97,659	5,443		103,102
Total	7,545	568,643	6,794,206	17,234,643	262,137	24,867,174

Note: (A) Estimated for use in synthetic liquid fuels production in accordance with specifications and procedures established for this survey.
(B) Willis and Davis beds, Eagle Valley field.
(C) Davis bed, Eagle Valley field.
(D) Identified as Indiana No. 5.

Commercial Coal Production

Trends in Production. The earliest record of coal production in Illinois by the U.S. Department of the Interior was in 1833 and amounted to 6,000 tons. Since that time, U.S. Bureau of Mines data indicate that a total of 3,084,075,000 tons of coal have been produced to the end of 1948. Achieving its maximum annual production of 89,291,000 tons in 1918, the annual production in Illinois has followed the general rise and fall of industrial activity for the entire country. Coal production in 1932, a year of serious depression, was only 33,475,000 tons. Since 1940 production has ranged from 50 to 77 million tons annually, with a total of approximately 65,342,000 tons in 1948, the last year of record.

Prior to 1911 all of the Illinois coal production of record was obtained from underground operations. Beginning with a production of 45,000 tons in that year, however, the amount of coal produced by stripping has increased steadily, with the result that the proportion of strip-mine production to total State production was 26.9 percent in 1948.

Beginning in 1924, the mechanical loading of underground coal, commonly used as an index of underground coal mechanization, has increased rapidly until in 1948 approximately 90 percent of the total underground production was mechanically loaded.

In common with most other important coal-producing states, average size of mines has increased in Illinois. In consequence, the number of active mines has decreased from a high of 784 in 1934 to 266 in 1948, of which 220 were underground operations and 46 were strip mines. The average number of employes has also decreased in approximately the same period from 100,000 in 1923 to 32,000 in 1948.

With increases in strip mining and in mechanization of underground operations, as detailed above, the average productivity in tons per man per day in the Illinois coal field has increased from 4.18 in 1914 to 8.94 in 1948. A special study of productivity by the U. S. Bureau of Mines in 1945 indicated that in that year the average production per man per day was 7.85 tons in underground mining and 18.52 tons in strip mining. In 1948, the average productivity per man per day in strip mining was also 18.52 tons.

Coal Beds Mined. The largest production in Illinois is obtained from the No. 6 bed, which was worked in 22 counties in 1948. The annual report of the Illinois Department of Mines and Minerals for 1948 indicates that in 1948, 71.5 percent of total production was obtained from coal No. 6, 23.7 percent from coal No. 5, 3.1 percent from coal No. 2, 1.3 percent from coal No. 7, and 0.4 percent from coal No. 1.

Thickness of Coal Beds. The thicknesses of coal beds being mined by commercial operations in Illinois vary from slightly less than 2 ft to 9 ft 6 in., the weighted average thickness being approximately 6 ft 8 in. A special study by the U. S. Bureau of Mines in 1945 on underground and strip mining in the United States indicated the following percentages of production in Illinois by thickness of bed:

Percentage of Underground and Strip Mining in Illinois

Bed Thickness	Percent of Total Production	
	Underground	Strip
Less than 2 feet	-	0.7%
2 to 3 feet	-	3.3
3 to 4 feet	0.6%	24.4
4 to 5 feet	7.7	32.9
5 to 6 feet	12.0	12.1
6 to 7 feet	21.6	23.1
7 to 8 feet	32.1	3.1
8 feet and over	26.0	0.4
Weighted average thickness	7.2 feet	4.9 feet

Quality of Coal. (See Exhibit No. 4 for references below) The coal beds of Illinois range from high-volatile C to high-volatile A bituminous in rank, with the rank increasing regionally from the north toward the south. With the exception of production from the No. 5 and No. 6 coals in eastern Perry, Jackson, Jefferson, Franklin, Williamson, Hamilton, White, Gallatin and Saline Counties, which are high-volatile B bituminous in rank, the present commercial production in the remaining portions of Illinois is high-volatile C bituminous in rank. The only coals of high-volatile A bituminous rank in Illinois are those in the southeastern portion of the northern Gallatin County field and those in the Eagle Valley field of southern Gallatin County and southeastern Saline County.

In general, Illinois coals are similar in quality to coals of Indiana and West Kentucky, constituting a readily marketable industrial and railroad fuel. Illinois coals are commonly medium to high in moisture, medium to high in ash, and variable as to sulfur.

Specific representative analyses of the coal beds determined to contain reserves for potential synthetic liquid fuels plant supply are presented in the summary and detailed tabulations accompanying this report as Exhibit No. 9. In large part, the available analyses of coal beds in Illinois have been obtained from operating mines, which were or are primarily located in the higher quality beds. For this reason, the analyses may not be fully representative of the entire reserves in any specific county.

The following ranges in selected items of analysis summarize the general quality of the individual Illinois beds considered during this survey, the beds being listed in descending order:

(References: 14, 24)

General Quality of Illinois Coal Beds, as Indicated by Selected Typical Items of Analysis for Available Representative Samples
(Mostly Mine Samples, As-received Basis)

Coal Bed	Item of Analysis		Representative Low	Representative High
Coal No. 7	Moisture	(percent)	12.0%	18.0%
	Ash	"	9.0	15.0
	Sulfur	"	2.5	3.5
	Btu		10,000	11,300
Coal No. 6 (Central and northern)	Moisture	"	12.0%	19.0%
	Ash	"	8.0	14.0
	Sulfur	"	3.0	4.0
	Btu		9,500	9,500
Coal No. 6 (Southern)	Moisture	"	8.0%	10.0%
	Ash	"	7.0	10.0
	Sulfur	"	0.9	3.0
	Btu		11,700	12,600
Coal No. 5 (Central and northern)	Moisture	"	11.0%	16.0%
	Ash	"	9.0	15.0
	Sulfur	"	2.0	4.0
	Btu		10,400	12,000
Coal No. 5 (Southern)	Moisture	"	6.0%	11.0%
	Ash	"	8.0	12.0
	Sulfur	"	2.5	4.5
	Btu		11,700	12,800
Coal No. 2	Moisture	"	11.0%	17.0%
	Ash	"	5.0	10.0
	Sulfur	"	2.0	7.0
	Btu		10,500	11,800

Analyses for Davis and Willis coal beds which do not contain reported reserves for potential synthetic liquid fuels plant supply, are not contained in this tabulation.

Distribution and Use. Approximately 88 percent of present commercial production is loaded directly at the mines into railroad cars or trucked to railroads or waterways for shipment to destination. Except for coal used at the mines (approximately 2 percent) the remaining production is loaded into trucks. Principal railroad carriers serving the coal fields of Illinois, in the approximate order of tonnages loaded for shipment, as reported by mine operators, are as follows:

Chicago, Burlington & Quincy
Illinois Central
Chicago & Illinois Midland
Missouri Pacific
New York Central
Chicago & Northwestern
Minneapolis & St. Louis
Gulf, Mobile & Ohio
Wabash
Chicago & Eastern Illinois
Atchison, Topeka & Santa Fe
Springfield Terminal
Litchfield & Madison
Chicago, Rock Island & Pacific
Galesburg & Great Eastern
Baltimore & Ohio

A large percentage of Illinois coal production is consumed within the State. In 1945, 25,868,000 tons were shipped to destinations in Illinois. In addition, 23,167,000 tons were used for railroad fuel and 5,670,000 tons were shipped by truck for consumption, probably relatively close to the coal mines. In the same year, 4,370,000 tons were shipped to Iowa, 3,974,000 tons to Missouri, 2,200,000 tons to Wisconsin, 2,000,000 tons to Indiana, 1,200,000 tons to Minnesota, and minor amounts to Michigan, Nebraska, South Dakota, Arkansas, Kansas, Tennessee, and Mississippi. Of shipments other than for locomotive fuel and by trucks, approximately 26,700,000 tons were distributed to industrial users, 13,800,000 tons to retail yards, and 285,148 tons for by-product or water gas manufacture.

In 1945 the percentages of production of Illinois coal by consolidated size groups were as follows:

1945 Percentage of Production of Illinois Coal

Coal Size Groups	Percent
Resultant and dedusted screenings with top size over 3/4 in. and not exceeding 2 in.	34.3%
Lump coal and double screened coal with top size over 2 in.	31.7
Modified mine run with top size over 2 in.	23.6
Double screened coal with top size not exceeding 2 in.	5.3
Resultant and dedusted screenings with top size not exceeding 3/4 in.	5.1

Future Coal Requirements. The demand for Illinois coal, used largely for industrial, power generation, railroad and domestic fuel, varies closely in accordance with nationwide industrial activity. Except in very minor amounts, Illinois coals are not adapted for special purpose uses, such as production of coke. According to Information Circular No. 7559, published by the U. S. Bureau of Mines in March 1950, only 505,000 tons of Illinois coal were received for coke production at slot-type ovens in 1947, whereas total U. S. coal received for such use approximated 97,000,000 tons in that year.

Except for possible increases in demand for future coke production, the future major requirements for Illinois coal appear to be confined to the generally industrial uses for which it is now being employed. At the 1948 production rate of approximately 65,340,000 tons, the total demand for Illinois coal in the next 50 years would approximate 3,267,000,000 tons. Since the average future rate of production over a 50-year period could obviously deviate from the 1948 rate in either direction, the above figure is used solely as an estimate of future requirements other than for the development of a synthetic liquid fuels industry.

Selection of General Areas of Coal Availability

Elimination of Unsatisfactory Areas. Upon completion of basic mapping and tabulation, each area of reserves was then examined as to location, extent, amount of recoverable reserves and relationship to other adjacent or nearby reserve areas. Isolated areas with insufficient reserves to provide at least one synthetic liquid fuels plant for a 40-year life were eliminated from consideration. Where large reserves of one or two principal beds were overlain or underlain by one or more coal beds of relatively limited extent, or of inferior quality, which would probably not be mined concurrently with mining of the more extensive beds, these intermediate beds were likewise eliminated. Substantial amounts of estimated reserves in Edgar, White, and Hamilton Counties were likewise eliminated because these were predominantly inferred in classification, with insufficient primary reserves to permit the delineation of a General Area of Coal Availability under the definitions established for this survey. The locations, coal bed designations, and amounts of estimated recoverable reserves of such eliminated areas are shown in the following table.

Eliminated Areas of Unsatisfactory Reserves

County	Location in County	Coal Bed	Estimated Recoverable Reserves (Thousands of Tons) Primary	Secondary	Total
LaSalle	Eastern	6	-	7,690	7,690
Henry	East-central	2	6,005	1,812	7,817
Marshall	Western	7	23,588	12,681	36,269
Knox	SW.	5	6,007	-	6,007
McLean	SW.	5	4,392	-	4,392
Tazewell	West-central	5	39,340	-	39,340
Schuyler	East-central	5	36,082	20,270	56,352
Christian	Southern	5	7,056	7,776	14,832
Edgar	SE.	5(B)	-	207,749	207,749
Montgomery	NW., NE., SW.	5	28,834	21,104	49,938
Fayette	NW., SE.	5	4,327	1,614	5,941
Macoupin	NW.	6	7,884	26,223	34,107
Greene	East-central	6	-	6,849	6,849
Jersey	SE.	6	-	19,569	19,569
Bond	NW.	5	2,543	-	2,543
Clinton	West, SE.	5	6,110	-	6,110
Marion	NE.	5	-	923	923
Jefferson	NE.	5	4,852	7,914	12,766
Washington	Central	5	12,689	-	12,689
St. Clair	South-central	5	16,250	-	16,250
Franklin	NE.	5	5,423	11,219	16,642
Lawrence	Eastern	5(B)	4,801	-	4,801
Wabash	North-central	5	6,523	5,920	12,443
White	SW.	5	-	105,613	105,613
White	SW.	6	-	191,220	191,220
Hamilton	Southern	5	-	432,450	432,450
Hamilton	Southern	6	4,934	1,035,758	1,040,692
Saline (A)	SE.	Davis	-	1,728	1,728
Saline (A)	SE.	5	-	1,660	1,660
Gallatin (A)	SW.	Davis	-	1,476	1,476
Gallatin (A)	Southern	Willis	-	4,341	4,341
Gallatin (A)	SW.	5	-	6,422	6,422
Gallatin (A)	SW.	6	-	4,536	4,536
Total			227,640	2,144,517	2,372,157

Note: (A) Eagle Valley field.
(B) Indiana Coal No. 5.

Deduction of Coal Reserves for Future Commercial Requirements. The total recoverable reserves in Illinois considered for synthetic liquid fuels, as previously shown, are estimated at approximately 24,867,000,000 tons. It is estimated that the future commercial requirements of Illinois coal for the next 50 years, based on the 1948 production rate of 65,340,000 tons, would be approximately 3,267,000,000 tons. There are therefore, approximately 21,600,000,000 tons available for the production of synthetic liquid fuels.

Substantial areas of both underground and strip reserves of coals of superior quality, continuity, or thickness in Illinois are in the hands of operating companies. While no attempt was made in this survey to confine estimates of reserves to areas not owned or controlled by operating or holding companies, some allowances for present ownership of both underground and strippable coal were probably unavoidably effected by excluding from the mapping and tabulation of reserves certain relatively minor areas not yet depleted, but lying within major areas of depletion as previously described under "Survey Methods and Procedure". It is considered that such eliminated reserves, at least some of which are probably being depleted by active mines, will supply some portion of the estimated future commercial requirements for Illinois coal. The total amount of potential supply thus provided, however, is considered as relatively minor in extent.

Demarcation of General Areas of Coal Availability. After elimination of the areas of unsatisfactory reserves, previously listed, the remaining areas of reserves were grouped into 31 General Areas of Coal Availability, in accordance with the definitions and procedures established for this survey. The locations, boundaries, and areas underlain by included coal reserves for each General Area are diagrammatically shown by Exhibit No. 10. A summary of detailed data pertaining to the General Areas is shown in Exhibit No. 9. These data include information on thicknesses of beds, depths of cover, rank and quality of coal, areas underlain by coal reserves, estimated recoverable reserves (by classes) and the daily capacity of synthetic liquid fuels plants, in thousands of barrels, which could be supported through a 40-year life by the estimated reserves.

Each General Area is less than 1,000 square miles in size and is of the approximate area of a single county, or less. County lines are crossed, however, when areas of adjoining, continuous reserves in one county properly belong with larger areas of reserves in another county. Where areas of continuous reserves in two or more adjoining counties each contain substantially greater reserves than the amount required to supply one synthetic liquid fuels plant having a daily capacity of 10,000 barrels, such areas are separated into two or more General Areas of Coal Availability.

The detailed data in Exhibit No. 9 are summarized in the table on the following page, which shows the estimated primary, secondary, and total reserves in each General Area, together with the daily synthetic liquid fuel plant capacity, in thousands of barrels, which could be supported through a 40-year life by such reserves, using either the hydrogenation or synthine process.

In connection with this table and with the detailed data, it should be noted that the total reserves estimated as available for synthetic liquid fuels production do not equal the sum of the estimated primary and secondary reserves in a number of General Areas. This reduction in total reserves conforms to the definition of availability of raw materials reserves which states that "--- the quantity considered sufficient for one or more plants is based upon a recoverable amount sufficient to supply such plant for a period of 40 years of which 20 years' supply is from primary reserves and the additional 20 years' supply is from either primary or secondary reserves."

The amounts of secondary reserves thus eliminated from the actual total of recoverable reserves are shown by the following tabulation, with quantities listed in thousands of tons:

Secondary Reserves Eliminated as Excess
(1,000 Tons)

General Area	Actual Totals Primary & Secondary	Totals Used	Amounts Eliminated
Peoria	453,076	443,432	9,644
Fulton-Knox	306,104	259,500	46,604
Logan	442,280	179,544	262,736
Macon	229,019	184,654	44,365
Menard	457,033	303,476	153,557
Sangamon	1,799,404	1,612,940	186,464
Northern Christian	1,287,199	899,764	387,435
Southeastern Montgomery	2,513,364	1,220,676	1,292,688
Madison	681,450	450,006	231,444
Bond	1,046,026	207,712	838,314
Clinton	1,291,965	726,830	565,135
Clay	385,650	123,022	262,628
Wayne	925,588	289,496	636,092
Jefferson	1,009,169	519,496	489,673
Washington	679,239	204,296	474,943
Perry	1,048,692	1,022,846	25,846
Franklin	1,015,719	673,788	341,931
Williamson	450,014	424,470	25,544
Saline	1,664,652	801,624	863,028
Total Amount Eliminated			7,138,071
Total Usable Reserves, All General Areas			15,356,946
Total Estimated Reserves in General Areas			22,495,017

Summary of General Areas of Coal Availability (A)
(As of January 1, 1950)

General Area Designation and Coal Bed		Estimated Recoverable Reserves (Thousands of Tons) Primary	Secondary	Total	Daily Plant Capacity (1,000 Barrels) Hydro-genation	Syn-thine
Southeastern Grundy	2	82,560	21,636	104,196	16	13
LaSalle-Grundy	2	99,520	72,745	172,265	27	21
Bureau-Putnam	2	190,293	29,512	219,805	34	26
Henry No. 6	6	161,583	56,151	217,734	31	24
Northern Knox	6	69,542	44,432	113,974	16	13
Marshall	2	40,679	23,881	64,560	10	8
Peoria	5&6	221,716	231,360	443,432(B)	67	51
Fulton-Knox	5&6	129,750	176,354	259,504(B)	38	29
Vermilion	6&7	228,141	132,278	360,419	55	43
Logan	5	89,772	352,508	179,544(B)	27	21
Macon	5	92,327	136,692	184,654(B)	28	21
Menard	5	151,738	305,295	303,476(B)	46	35
Sangamon	5&6	806,470	992,934	1,612,940(B)	240	187
Northern Christian	5&6	449,882	837,317	899,764(B)	137	106
Southeast Montgomery	6	610,338	1,903,026	1,220,676(B)	184	143
Macoupin	6	937,660	929,214	1,866,874	280	218
Madison	6	225,003	456,447	450,006(B)	68	53
Bond	6	103,856	942,170	207,712(B)	31	24
Clinton	6	363,415	928,550	726,830(B)	110	86
Marion	6	95,168	43,932	139,100	22	17
Clay	5&6	61,511	324,139	123,022(B)	20	15
Wayne	5&6	144,748	780,840	289,496(B)	46	36
Jefferson	6	259,748	749,421	519,496(B)	87	68
Washington	6	102,148	577,091	204,296(B)	31	24
St. Clair	6	499,659	419,461	919,120	141	110
Randolph	5&6	279,927	45,192	325,119	50	39
Perry	5&6	511,423	537,269	1,022,846(B)	161	125
Franklin	6	336,894	678,825	673,788(B)	111	87
Jackson No.5	5	258,243	47,965	306,208	50	39
Williamson	5&6	212,235	237,779	424,470(B)	71	55
Saline	5&6	400,812	1,263,840	801,624(B)	138	107
Total		8,216,761	14,278,256	15,356,946	2,373	1,844

Note: (A) Detailed data on General Areas are presented in Exhibit No. 9.

(B) Total primary and secondary reserves for synthetic liquid fuels plant supply in any specific General Area are limited by definition to twice the primary reserves.

Deduction of the 15,357,000,000 tons estimated as the total recoverable reserves for production of synthetic liquid fuels in the 31 General Areas from the total recoverable reserves of 24,867,000,000 tons considered in the entire State, leaves a balance of 9,510,000,000 tons, more than sufficient to satisfy the estimated future 50 years commercial requirements for Illinois coal (3,267,000,000 tons). It is possible that a portion of either synthetic liquid fuels supply or future commercial requirements will eventually be obtained from the 2,372,000,000 tons contained in the eliminated areas of unsatisfactory reserves itemized in a preceding section of this report, or from the 7,138,000,000 tons of excess secondary reserves eliminated from 19 of the 31 General Areas as shown above. It is likewise possible that present operating companies as of January 1, 1950 either own or control relatively minor amounts of reserves for future commercial production which were not included in the total amounts of reserves estimated herein as available for synthetic liquid fuels plant supply, as previously described under "Survey Methods and Procedure". There is also the probability of additional reserves being developed in areas for which there is not now sufficient information to warrant the estimation of reserves for the purpose of this report.

Under the definitions and procedures employed in this survey, and with the allowances specified for future commercial production, it is concluded that sufficient coal reserves are available in 31 General Areas of Coal Availability in Illinois to supply synthetic liquid fuels plants having a minimum capacity of 2,373,000 barrels per day using the hydrogenation process, or 1,844,000 barrels per day using the synthine process. It is probable that continued exploration and development of Illinois coal reserves will result in the discovery of additional reserves for both synthetic liquid fuels plant supply and future commercial requirements in areas not now containing sufficient information to permit the present estimation of reserves.

NATURAL GAS

The natural gas phase of the investigation included a study of the geology of the gas-bearing formations and of related data on natural gas in the State. Such study embraced all of the gas and oil fields in Illinois, with special reference to the quantity of gas to be recovered, the gas available for synthetic liquid fuels production, and cost of gas in the field.

Commercial natural gas development in Illinois started near Litchfield, Montgomery County, early in 1885. Additional exploration followed, between 1886 and 1920, with the development of several gas fields in southwestern Illinois. Production was from the geological formations of Pennsylvanian, Mississippian, Devonian and Silurian ages.

The reported annual gas production in Illinois in 1906 was 410,000 Mcf. The maximum production, in 1939, was 142,000,000 Mcf; this declined yearly thereafter to about 62,000,000 Mcf in 1948. It is estimated that the cumulative gas production from the State was about 1,050,000,000 Mcf, as of January 1, 1949, most of which was produced incidental to the production of oil. Gas is produced from some 30,000 oil and gas wells, from depths varying between 40 feet and 3,700 feet. During 1948, it is estimated that gas was produced at an average rate of 170,000 Mcf per day.

Formations of Devonian and Ordovician ages offer the best possibilities for future gas discoveries.

Almost all of the gas produced in large quantities is under contract to be processed by one of the gasoline plants in Illinois, and the residue gas, after processing, is also under contract. The average price of gas in the field is about 9 cents per Mcf. Natural gas produced in Illinois has an average heating value in the order of 1,100 Btu under standard conditions.

The following tabulation summarizes the essential data relative to reserves of natural gas in Illinois:

Summary of Estimated Recoverable
Natural Gas Reserves in Illinois
(Under Standard Conditions)

As of January 1, 1949	Mcf
Total	241,927,000
Commercial Requirements:	
Contract or To Be Used in Field	228,873,000
Total Undedicated Reserves	13,054,000

The appended map, Exhibit No. B-1, shows the oil and gas fields and the main natural gas pipe lines in Illinois. Detailed information pertaining to the oil and gas fields and the natural gas reserves is tabulated in Exhibit No. B-2.

Based on the foregoing, it appears that none of the natural gas deposits in Illinois could be considered an available reserve for synthetic liquid fuels production, since available information indicates that the total undedicated reserves in the entire State are less than the minimum reserve requirements for the purpose of this study, namely, undedicated natural gas deposits containing at least 225 trillion Btu, producible within a radius of 40 miles and having a heating value of not less than 400 Btu per cubic foot at standard conditions. Since the heating value of natural gas in Illinois is in the order of 1,100 Btu per cubic foot, the volume of gas reserves to meet minimum requirements for synthetic liquid fuels production would be about 204,500,000 Mcf. This is greatly in excess of the total undedicated reserves, shown in the previous tabulation as 13,054,000 Mcf. Discoveries of new fields and extension of known fields in the interim between January 1, 1949 and the date of this report warrant no change in this conclusion.

It is, therefore, concluded that there are no reserves of natural gas in Illinois available for use as a source of raw material for synthetic liquid fuels manufacture.

Detailed information pertaining to the natural gas survey, and the bases for the conclusions expressed herein, is contained in the report prepared by DeGolyer and MacNaughton, which accompanies this report as Appendix B.

OIL SHALE

The oil shale phase of the investigation included a study of the geology of the oil shale-bearing formations and of assay data on oil shale samples from various localities in Illinois.

The known oil shale-bearing formations in Illinois are the New Albany shale, the Decorah formation, and the coal-bearing formations of Pennsylvanian Age. The lithology of other formations present in Illinois appears to be unfavorable for the occurrence of oil shales.

Only 17 samples of oil shale from 11 localities in Illinois have been assayed for oil yield. All of these assays were made prior to 1923, and no additional sample or assaying of Illinois oil shales is known to have occurred since that year. The data available are entirely too meager to provide any reasonable basis for estimating the oil shale reserves of Illinois, and so far as known, no such estimate has been made.

The review of all available information indicates that none of the oil shales in Illinois are of sufficient richness and thickness to provide a reserve of raw materials for synthetic liquid fuels manufacture under the minimum requirements for this survey, which provide for an average oil content of at least 15 gallons per ton of oil shale, over a minimum of 25 feet in thickness and totaling not less than 100,000,000 tons of oil shale within an area of not more than 5 square miles.

It is therefore concluded that there are no oil shale reserves in Illinois suitable for use as a source of raw materials for synthetic liquid fuels manufacture.

Detailed information pertaining to the oil shale phase of the survey and the basis for conclusions expressed, are contained in the report prepared by DeGolyer and MacNaughton, which accompanies this report as Appendix C.

WATER SUPPLY

Hydrological Features

Coal reserves in sufficient quantity for producing a total of 1,844,000 barrels of synthetic liquid fuels daily by the synthine process are found in 31 General Areas in Illinois. The greatest concentrations of coal are found in the Sangamon River basin in central Illinois, and in the Kaskaskia, Big Muddy, and Saline River basins in the southern part of the State. The 31 General Areas of coal availability are shown in Exhibit No. 11 in relation to principal communities and the major streams and sources of water supply.

Illinois has sufficient water resources, if conserved, to supply all the synthetic liquid fuels plants for which coal is available.

The State is bounded on the west by the Mississippi River and on the south and east by the Ohio and Wabash Rivers. The upper central part of the State is drained by the Illinois River which flows from the northeast corner of the State to its junction with the Mississippi at Grafton. Much of the southwestern part of the State is drained by the Kaskaskia River.

The average annual rainfall in Illinois ranges from 33 inches in the northern part of the State to 44 inches in the southern areas. During wet years, the rainfall has been more than 50 percent greater than the average, and during extremely dry years, such as 1930, it was 75 percent of the average.

The runoff in the streams of the State varies from about 8 inches per year in the northern areas of the State to approximately 14 inches per year in the southern part of Illinois, with a mean annual runoff throughout the State amounting to 10 inches annually or about 0.75 cfs per square mile.

Water Requirements for Synthetic Liquid Fuels Plants

Water is quite essential for synthetic liquid fuels production, not only for steam generated for power but for synthesis gas production in connection with the synthine process and hydrogen manufacture in the hydrogenation process. In both processes, water is used for cooling purposes and for boiler and cooling tower blowdown to remove accumulation of salts left by the evaporated water.

In a hydrogenation process unit plant, there are approximately 35 billion Btu and in a synthine process unit plant 54 billion Btu that have to be dissipated daily by cooling waters.

Quantity. The following table shows the quantity of water required both for process and domestic use in connection with a unit synthetic liquid fuels project:

Approximate Water Requirements for a Daily Output of 10,000 Barrels of Products

	Make-up		Consumed		Returned	
	Mgd	Cfs	Mgd	Cfs	Mgd	Cfs
Hydrogenation Process:						
Plant Use	7.29	11.28	5.36	8.29	1.93	2.99
Domestic Supply	1.73	2.68	0.43	0.67	1.30	2.01
Total	9.02	13.96	5.79	8.96	3.23	5.00
Coal Synthine Process:						
Plant Use	11.15	17.25	7.71	11.93	3.44	5.32
Domestic Supply	1.94	3.00	0.49	0.76	1.45	2.24
Total	13.09	20.25	8.20	12.69	4.89	7.56

Process. It is obvious that the water requirement for any specific project would depend upon the choice of either the hydrogenation or the coal synthine manufacturing process, being 45 percent greater for the latter process. However, water costs represent as a rule less than 2 percent of the total costs of products, exclusive of return on investment. Therefore, it appears possible and on the safe side to adopt the coal synthine process requirements as the basis for estimates of water quantities and costs.

A detailed statement of the coal synthine process water requirements, given in Exhibit No. 12, shows most of the water use in the plant to be for cooling purposes. The estimates assume recirculation of cooling water over cooling towers. Once-through cooling without the towers would require about eighteen times more water but the consumptive use would be much smaller. It would be feasible only for a unit development located on the bank of a large river or a large lake. The cost of delivering large quantities of water to a remote site would be relatively prohibitive.

In estimating water supplies for the General Areas of Coal Availability in Illinois, total plant requirements have been used without allowance for water returned to the stream as possible waste or sewage. Such waste water might be returned at a considerable distance from the point of withdrawal and might contain a considerably higher percentage of natural salts than the original water diverted and be less desirable for some purposes. Water use data and cost estimates are based upon average annual demands. Water required for complete development of the fuel resources of each of the General Areas of Coal Availability in Illinois varies with the coal reserves available. It ranges from 16 cfs in the Marshall

General Area based on 8,000 barrels per day production using the synthine process, to 441 cfs in the Macoupin General Area. The total quantity required for concurrent full development in all the General Areas within the State would be 3,734 cfs or 2,414 mgd, using the synthine process.

Domestic. The amount of water to be supplied for domestic purposes, as shown in the previous table, is affected not only by the total number of workers (determined by the choice of process), but also by the proportion of those workers that would come from already established communities having their own water supplies. Again, in view of the small relative cost of water as compared with the other items contributing to total product costs, variations in conditions affecting domestic water requirements are relatively small. It is, therefore, assumed for this report that domestic water would have to be supplied for all the workers in plant and mine, the service people and the families of both. A per capita allowance of 150 gallons per day has been made uniformly for the population of the plant city. This population is arrived at by multiplying the number of plant and mine workers by five, and using the synthine process, amounts to 12,955 persons.

Quality. Process water must be relatively clear and free from turbidity and substances capable of clogging condenser tubes, cooling towers, and other equipment. The dissolved solids content is not of major importance except that a high concentration would require frequent blowdown of cooling towers and boilers and would increase the amount of make-up water. Boiler feed waters must be free of organic matter and insoluble solids and suitable for softening. Water for drinking and sanitary purposes in the mines and plants and in the communities serving the developments would have to be potable and of a quality satisfactory to the public health authorities of the State. Water softening might be justified for domestic use.

Water Resources

Water for synthetic liquid fuels plants in Illinois could be obtained directly from the Mississippi, Illinois, Ohio, or Wabash Rivers, with or without storage reservoirs, depending upon the total quantity of water needed; from impoundments on tributaries of these rivers in Illinois; from Lake Michigan; or from underground sources. The most important sources of water supply for synthetic liquid fuels development in Illinois are the large rivers and impoundments on the tributaries of these rivers. A detailed discussion of each of these possible sources is presented in the following paragraphs. The runoff records at the various gaging stations have been obtained from appropriate U.S. Geologic Survey Water-supply Papers. The stream gaging stations used for stream flow studies are shown in Exhibit No. 13.

Surface Water. The most readily available sources of surface water for a synthetic liquid fuels development in Illinois are the Mississippi and Illinois Rivers.

Mississippi River. The Mississippi River would be the logical source of water for synthetic liquid fuels plants in five General Areas in the southwestern part of the State. In addition, if all of the coal resources in five additional General Areas in the south central part of the State were fully developed, some of the water for these areas could be obtained economically from the Mississippi River.

Stream flow records of the Mississippi River in the vicinity of the coal areas in Illinois are limited, but the flow characteristics are indicated in the following table:

Flow of the Mississippi River

	Gaging Stations	
	Alton, Ill.	Chester, Ill.
Drainage Area (Sq Mi)	171,500	712,600
Period of Record (Water Yr)	1934-1937 1940-1946	1943-1946
Mean Flow (Cfs)	93,920	221,425
Minimum Monthly (Cfs)	22,340	80,760
Month of Occurrence	Aug. 1936	Dec. 1943
Minimum Daily (Cfs)	15,000	67,400
Date of Occurrence	Dec. 30, 1933	Jan. 22, 1944

Illinois River. After the Mississippi River, the Illinois River would be the most important source of water for a synthetic liquid fuels development in Illinois. From the point where it is formed by the confluence of the Des Plaines River and the Kankakee River, the Illinois River runs for a distance of 200 miles through the coal area of central Illinois.

The Illinois River would be the most logical source of water for synthetic liquid fuels plants in five General Areas all located in the central part of the State. Water from the Illinois River might also be obtained for three additional General Areas, if the coal resources in these Areas were developed to the extent that local supplies would be inadequate.

The flow characteristics of the Illinois River are shown in the following table:

Flow of the Illinois River

	Gaging Stations			
	Marseilles	Kingston Mines	Meredosia	At Mouth (A)
Drainage Area (Sq Mi)	7,640	15,200	25,300	29,100
Period of Record	1920-46	1940-46	1939-46	-
Mean Flow (Cfs)	11,898	13,197	20,113	23,100
Minimum Monthly Flow (Cfs)	3,670	3,905	5,097	5,850
Month of Occurrence	9/39	1/45	1/45	-
Minimum Daily Flow (Cfs)	1,460	2,300	3,060	3,520
Date of Occurrence	10/16/43	9/27/43	9/1/45	-

Note: (A) Estimated from records of Meredosia.

Ohio River. The Saline General Area, in the southern part of the State, is the only General Area of Raw Material Availability in Illinois adjacent to the Ohio River. In addition, the Williamson General Area could be served from the Ohio River. Water for synthetic liquid fuels plants in these Areas could be withdrawn from the Ohio River within a 45-mile stretch below the mouth of the Wabash River.

There are two gaging stations on the Ohio River along the Illinois border, one at Metropolis, Ill., 96 miles below the mouth of the Wabash River, and the other at Golconda, Ill. The flow of the Ohio River at Metropolis and at two of the upstream gaging stations is shown in the following table:

Flow of the Ohio River

	Gaging Stations		
	Evansville, Ind.	Golconda, Ill.	Metropolis, Ill.
Drainage Area (Sq Mi)	107,000	143,900	203,000
Period of Record	1941-1947	1941-1947	1929-1947 (A)
Mean Flow (Cfs)	121,400	153,300	244,500
Minimum Monthly Flow (Cfs)	13,160	16,680	22,700
Month of Occurrence	10/1943	10/1940	10/1930
Minimum Daily Flow (Cfs)	-	-	15,000
Date of Occurrence	-	-	7/20, 21, 30, 1930

Note: (A) 1929-1934 data from Corps of Engineers

The drainage area of the Ohio River where water would be diverted from the river for synthetic liquid fuels in Illinois is about 140,000 square miles. The minimum monthly flow in 1930 at

this point is estimated to have been about 8,000 cfs. Regulating reservoirs constructed since 1930 would have increased this minimum flow to 10,000 cfs. These regulating reservoirs also reduce the severity of minimum daily flows.

Wabash River. The Saline General Area is the only General Area of Raw Material Availability adjacent to the Wabash River. Water for synthetic liquid fuels plants in this Area could be taken either directly from the Ohio River or from the backwater of the Ohio in the Wabash River. Water for synthetic liquid fuels plants in the Wayne General Area might be obtained from the Wabash River with diversion works located below Mt. Carmel.

The flow characteristics of the Wabash River where it borders Illinois are shown below:

Flow of the Wabash River

	Gaging Stations		
	Vincennes, Ind.	Mt. Carmel, Ill.	At Mouth (A)
Drainage Area (Sq Mi)	13,700	28,600	33,100
Period of Record	1931-1948	1928-1948	-
Mean Flow (Cfs)	10,304	24,860	28,800
Minimum Monthly Flow (Cfs)	1,303	2,372	2,740
Month of Occurrence	Aug. 1936	Aug. 1936	-
Minimum Daily Flow (Cfs)	770	1,620	1,880
Date of Occurrence	Aug. 5, 1934	Sept. 28, 1941	-

Note: (A) Estimated from record at Mount Carmel.

Impoundment of Smaller Rivers. Besides the four major rivers, there are numerous tributary streams in or near the General Areas of Raw Material Availability that could furnish dependable supplies of water for synthetic liquid fuels plants if storage reservoirs were constructed to impound the seasonal flows of these streams. The characteristics of these streams are summarized in Exhibit No. 14. The average annual runoff of these streams varies from 0.6 cfs per square mile of drainage area in the northern part of Illinois to about 1.0 cfs per square mile in the southern section.

Lake Michigan. An economical source of water for a very large synthetic liquid fuels development along the Illinois River would be Lake Michigan. Water could be diverted from the lake into the Chicago Sanitary and Ship Canal and thence into the Illinois River at comparatively small cost. This arrangement would cost less than building storage reservoirs on tributaries of the Illinois River for supplementing low flows during dry weather. The General Areas above Pekin might be served in this manner. Full development of the coal resources for synthetic fuels in these Areas would require 205 cfs from the river. If water were diverted from Lake Michigan to furnish this quantity

by augmenting the low river flows during the driest periods, the average diversion from the lake during such a period would be only 50 cfs.

The first substantial diversion of water from Lake Michigan into the Illinois River basin for dilution of wastes from the Chicago area occurred in 1900. Since then there has been almost endless litigation and controversy over the quantity of water that might be diverted for dilution of Chicago's wastes and over the effect of the diversion of the water level of the Great Lakes.

From a high average annual diversion of 8,407 cfs in 1928, which was authorized by the War Department in addition to 1,563 cfs of pumpage for the Chicago water supply, the average annual diversion was reduced stepwise by the Supreme Court decree as follows:

	Cfs
July 1, 1930	6,500
December 31, 1935	5,000
December 31, 1938	1,500

These allowances are in addition to the domestic pumpage of Chicago, which at present amounts to approximately 1,700 cfs. A petition by the State of Illinois in 1940 for a temporary increase in the diversion to 5,000 cfs was denied by the Supreme Court.

A request for additional diversion from Lake Michigan for industrial use in Illinois is likely to meet with considerable opposition from the other states on the Great Lakes and Canada, especially since water supplies from other sources are available. Therefore, Lake Michigan has not been further considered as a source of water supply in this report.

Water Quality and Stream Pollution. The quality of surface waters in Illinois varies with the seasons and the amount of runoff. During flood periods, the waters are turbid but low in dissolved mineral matter. During periods of low flow, the waters are less turbid but harder and with greater concentrations of dissolved solids. Where water supplies are obtained directly from impounding reservoirs, quality is generally less variable, and the turbidity is lower than waters pumped directly from flowing streams. Analyses of surface waters of Illinois are shown in Exhibit No. 15.

For once-through cooling, the concentration of dissolved solids is relatively unimportant, but where cooling towers are used, a high concentration necessitates excessive blowdown and greater water consumption. From this standpoint, a turbid water would be more satisfactory than one with high dissolved solids, because the turbidity can be removed economically by sedimentation.

The turbidity of Illinois surface waters is indicated in the following table:

Monthly Variation in Turbidity of River Waters
(in ppm)

	Year	Minimum	Maximum	Average
Mississippi River at St. Louis	1945	160	2,900	1,265
Ohio River at Louisville	1949	5	357	102
Illinois River at Peoria	1949	22	210	92

The frequency of various turbidity concentration levels in the major rivers is shown in the following table:

Average Number of Days in a Year That Turbidity is below 50, 100, and 150 Ppm in River Water Supplies

Water-works Location	No. Days Turbidity (ppm) was Below			Period of Record (all years inclusive)
	50	100	150	
Mississippi River at Moline	136	226	357	1935-1945
Mississippi River at Alton	60	142	336	1936-1945
Missouri River at St. Louis	7	14	80	1935-1945
Mississippi River at East St. Louis (A)	51	131	309	1937-1945
Illinois River at Peoria	242	299	364	1935-1944
Ohio River at Cairo	17	105	312	1936-1945

Note: (A) Intake is on the Illinois side of the river only 2 miles below the mouth of the Missouri at which point the turbid Missouri River water is not completely mixed with Mississippi River water.

Peak daily values for the Mississippi River at St. Louis and the Ohio River at Cairo are about 5,000 and 1,500 ppm, respectively.

In estimating the cost of water-supply works for synthetic liquid fuels plants, it has been assumed that a storage basin with one day's capacity would be built at each of the plants. This basin would serve as a settling basin to remove most of the turbidity in the raw water. Occasionally, it might be necessary

to add coagulant to the raw water to improve sedimentation, but the cost of such chemical treatment would not be significant. Satisfactory domestic water supplies can be obtained from the rivers by means of conventional coagulation and filtration. Boiler make-up waters would require softening, and softening of domestic supplies might be justified in some of the Areas since the Illinois waters are comparatively hard. The additional cost of softening the domestic water would not affect appreciably the over-all costs of water.

The mineral concentration in the surface waters in Illinois is highest in the upper Illinois River area and is lowest on the tributaries of the Ohio River. However, in none of the Areas are the surface waters so mineralized as to cause any difficulty in using them for cooling purposes.

The Mississippi River water in the stretch along Illinois ranges in temperature from 35 deg F in extreme winter to more than 85 deg F during the peak of summer. Somewhat greater variations in temperature are found in smaller streams and rivers.

Sewage and industrial waste pollution do not seriously affect the suitability of the surface waters of Illinois for water-supply purposes except in the Illinois River. In 1949, sewage and industrial wastes equivalent in strength to sewage from a population of 7,310,000 persons were treated in sewage treatment plants of the Chicago Sanitary District prior to discharge into the Illinois waterway. The resulting pollution load was equivalent to untreated sewage from more than 1,000,000 persons. Continued improvement in the treatment of wastes by the Chicago Sanitary District may be expected to reduce the pollution of the Illinois River in the future, but some of the effects will not be eliminated for many years, if ever.

Natural purification improves the condition of the Illinois River somewhat along its length, but discharges of wastes from Joliet, Peoria, and Pekin tend to prevent any real cleanup. In the Peoria-Pekin Area, for example, in addition to the treated sewage from about 130,000 persons, industrial wastes with a population equivalent of about 300,000 are discharged into the river.

While the Illinois River water could be made safe for domestic purposes by modern methods of purification, it is too grossly polluted to be an entirely satisfactory source of drinking water. Therefore, in those Areas where the process water would be obtained from the Illinois River, it is assumed that ground water supplies or surface supplies from tributary streams would be developed for domestic purposes. The ground water resources in northern and central Illinois would not be adequate for the industrial requirements, but enough water could be obtained in this manner to meet the domestic needs.

Ground Water. Ground waters are used extensively for small municipal supplies in northern and central Illinois. In the northern part of the State, the ground waters are derived principally from rock wells up to 2,500 feet in depth which penetrate limestone and St. Peter, Dresbach, and Mount Simon sandstones. In the central part of the State, they are obtained from drift deposits of sand, gravel, and clay. The maximum depth of these aquifers is about 300 feet.

The best sources of ground water in Illinois are the alluvial and glacial deposits in and near the larger river bottoms, such as are found in the Peoria-Pekin district. In this area, 85 mgd are pumped from drift wells, 40 to 90 feet deep for municipal and industrial water supplies.

For individual 10,000-barrel-per-day synthetic liquid fuels plants, sufficient water possibly could be developed from wells in the vicinity of the Illinois River, especially in the 40-mile stretch of river below Pekin. Such possibilities also exist along the Mississippi River, Wabash River, and along the Ohio River in Gallatin County. The feasibility and cost of such development must be proved, however, in each instance by test drilling and pumping, both of which are beyond the scope of this investigation. Where the wells can be developed, the ground storage serves as a substitute for surface storage reservoirs.

The relatively small domestic supplies necessary in connection with synthetic liquid fuels plants could be obtained in the northern, central, and possibly the southern parts of the State.

The location of the principal ground water resources in Illinois is shown on Exhibit No. 16.

Quality. As noted earlier, the ground waters in Illinois are highly mineralized and generally hard. Some of the drift wells produce water high in iron, while water from rock wells in the northern part of the State are often sulfurous in taste and odor, and are high in chlorides. Analyses of the more important sources of ground water in the coal areas of Illinois are shown in Exhibit No. 17.

Most of these well waters are used by the municipalities without treatment other than disinfection with chlorine. However, the waters are highly mineralized and in some locations iron removal, filtration, and softening are provided. The need for such treatment depends upon the exact characteristics of the water in any particular area. Chlorides cannot be removed economically, and where they are higher than 250 ppm, the water could not be used satisfactorily for domestic purposes. As long as its mineral quality is satisfactory, the use of ground water is desirable because of its uniformly low temperature.

Water Uses - Existing

Before taking up the discussion of the development of the water resources in Illinois for synthetic liquid fuels production, the water demands of present users are considered.

Municipal and Industrial Uses. A few large towns or cities in the coal-bearing area of Illinois and most of the smaller communities obtain their water from wells. The larger cities, such as Springfield, East St. Louis, Bloomington, and Kankakee, all have surface water supplies. At Springfield and Bloomington, impounding reservoirs have been built. Peoria and Pekin are the only large communities in the coal area using ground water supplies for municipal purposes. Industrial water supplies generally are obtained from the rivers except in the Peoria-Pekin area where there has been a substantial industrial ground water development.

Mississippi River. In the vicinity of the coal-bearing area of Illinois, the Mississippi River and its smaller tributaries are used to supply approximately 40 cfs of municipal water to part of the population of St. Louis and to other smaller communities. Many industrial supplies are also obtained from the Mississippi River.

Illinois River. The upper end of the Illinois River is heavily polluted. Sewage and industrial wastes from the Sanitary District of Chicago are treated and discharged through the Chicago Sanitary and Ship Canal into the Des Plaines and Illinois Rivers. The Chicago sewage, which averages 1,700 cfs or 1,100 mgd, originates principally through the municipal water supply pumped from Lake Michigan. In addition to the water supply, the Sanitary District has been authorized by the U.S. Supreme Court to divert an annual average of 1,500 cfs from Lake Michigan for the dilution of the sewage in the Illinois Waterway. The domestic water consumption and sewage flows are relatively constant througout the year. The dilution water, on the other hand, is diverted at high rates primarily during period of low river flow. For example, the maximum daily diversion in 1946 was 4,926 cfs. At other times when the flow in the river was naturally high, no lake water was diverted.

The Illinois River water is not used for public water supplies, except at Grafton near the mouth of the river, and the river is generally considered to be too polluted for safe swimming. The water is used extensively for process and cooling purposes, and it should be satisfactory for synthetic liquid fuels plants. It would have to be filtered for boiler feed purposes and for other process uses that require high quality water.

Tributaries of the Illinois River are used to supply approximately 35 cfs of domestic water to a population in excess of 250,000.

Ohio River and Wabash River. The Ohio and Wabash Rivers are used for municipal and industrial purposes in the vicinity of the coal-bearing portion of Illinois. The flows of these rivers are so great, however, that the effect of these uses is assumed negligible in respect to synthetic liquid fuels development in Illinois.

Navigation. The amount of water required to maintain a navigable channel in the Illinois River is critical in relation to synthetic liquid fuels plant demands only during periods of low river flow. The existing requirements for navigation are discussed in the following paragraphs.

Mississippi River. Under present open river flow conditions, the Corps of Engineers estimates that a minimum flow of 70,000 cfs is required throughout the Alton-St. Louis stretch to maintain a 9-foot channel for navigation. A flow of 54,000 cfs is required for the same depth of channel below St. Louis. Completion of the lock and canal around the Chain of Rocks (set for 1951 or 1952) will provide a 9-foot channel up to the mouth of the Missouri, whenever the combined flow of the Mississippi and Missouri Rivers exceeds 54,000 cfs. Above Lock and Dam No. 26 at Alton, a 9-foot channel is maintained by a series of locks and dams; below Alton there are no locks except for the one under construction on the Chain of Rocks Canal.

Illinois River. By means of a series of locks and dams a 9-foot deep waterway is maintained in the Illinois River for navigation between Lake Michigan and the Mississippi River.

The minimum flow required for navigation on the river has been estimated, tentatively, as 3,000 cfs at Beardstown. In general, low flows of the river at Beardstown range from 4,000 to 5,000 cfs. In the eight years of record since 1939, when the average annual diversion from Lake Michigan was reduced by the court decree to 1,500 cfs, the flow at the Meredosia gage, 17 miles below Beardstown, has been less than 3,500 cfs for only two days, August 31 and September 1, 1945.

Hydroelectric Power. There are several hydroelectric power developments in Illinois, the largest of which are the following:

Hydroelectric Power Developments

Location	Ownership	Installed Capacity (Kw)
Mississippi River:		
at Keokuk, Iowa	Union Electric Power Co.	116,000
at Rock Island	United States	2,750
at Moline	Iowa-Illinois Gas & Electric Co.	3,600
Illinois Waterway:		
at Lockport	Chicago Sanitary District	21,000
at Marseilles	Illinois Power Co.	2,380
Rock River:		
at Dixon	Illinois North Utility Co.	3,200
at Sterling (2)	Illinois North Utility Co.	3,670
Fox River at Dayton	North Counties Hydroelectric Co.	3,670

Control Flow. In most parts of the State, it would not be possible to impound or divert the full flow of a river or a stream. Although there may be no substantial existing downstream water use, some minimum flow certainly will be required to satisfy the riparian owners. For estimated storage requirements, the minimum flow below which water could not be withdrawn for synthetic liquid fuels plants has been assumed as that flow which is normally exceeded 90 percent of the time. This flow is defined as the control flow.

Special allowances are made where water demands in excess of the control flow are known to exist, and it is recognized that the uniform control flow assumed would not be adequate in all cases because of special local requirements. However, a control flow allowance is considered reasonable for determining the quantity of water that would be available for synthetic liquid fuels plants.

Flood Control and Conservation. The low flows of the Mississippi River are regulated to some extent by reservoirs on the tributaries and are affected somewhat by the diversion of water from Lake Michigan through the Chicago Sanitary and Ship Canal into the Illinois River. The reservoirs include six 40- to 70-year-old reservoirs on the headwaters of the Mississippi River in Minnesota operated primarily for the benefit of navigation on the Mississippi River; 32 other reservoirs are used primarily for power-storage regulation at the Bagnell Power Dam on the Osage River, the Kanopolis Flood Control Dam on the Smoky Hill River, and the Fort Peck Reservoir on the Missouri River in Montana.

Some regulation of the low flow of the Mississippi River at St. Louis may be provided under the plan of operation for the Missouri River. Where water is to be released from reservoirs to maintain 15,500 cfs in the Missouri River at the mouth of the James River in South Dakota during the navigation period (March to November) and to maintain a flow of 5,500 cfs at this point during other seasons. This program will affect the amount of water the Missouri River will add to the flow of the Mississippi River at St. Louis.

Water Uses - Proposed

Possible future water developments, which are under consideration by the Corps of Engineers and other agencies, are discussed in this section. Water uses that might arise from the development of synthetic liquid fuels plants in Illinois are discussed in the section of this report entitled, "Water Available for Synthetic Liquid Fuels Development", following.

Flood Control and Conservation. There are no existing flood control reservoirs in Illinois but the construction of 12 dams in the Illinois River basin is being considered by the Corps of Engineers. While all of these reservoirs are intended primarily for flood control, five of them would have pools which would be available to improve navigation in the Mississippi River or for water-supply purposes. Two of the proposed reservoirs could be built with higher dams to yield additional storage. The Corps of Engineers, Upper Mississippi Valley Division, has estimated "... that each additional acre-foot of water which could have been made available to the Mississippi River below the mouth of the Missouri River when needed during deficiency periods is worth about 60 cents per year. It should be noted that this figure is only for dependably delivered storage and not storage at the reservoir site..."

Storage would be worth a great deal more than this to a synthetic liquid fuels development. However, in preparing cost estimates, for comparative purposes, in those areas where storage might be available to synthetic liquid fuels plants from proposed flood control reservoirs, the costs have been based on the cost of a small reservoir located at these Federal reservoir sites.

Two reservoirs, Carlyle and Shelbyville, are being considered by the Corps of Engineers on the Kaskaskia River. The Carlyle Reservoir was authorized by the Flood Control Act of 1938.

Hydroelectric Possibilities. The Mississippi River, where it borders Illinois, is not suitable for hydroelectric power production because of the relatively flat slope of the river, except where the three existing plants have been built. The construction of high dams is not feasible because they would flood railroads, urban areas, and other valuable property. A high power

dam at Commerce, 40 miles above Cairo on the Mississippi River, investigated by the Corps of Engineers in 1940 was deemed not practical for economic and other reasons.

On the Illinois Waterway, provision has been made for future additional power generation at the navigation dams at Brandon Road, Dresden Island, Marseilles, and Starved Rock, the latter three being in or near the coal areas. The possible operating heads at these four dams are 33, 19, 22, and 16 feet, respectively. The development of power below Starved Rock is not economical because of the flat gradient of the river.

The head available for power production on the Wabash and Ohio Rivers in Illinois is small. The only existing power plant on the Ohio River is the 80,320-kw unit at Louisville, and there are no hydroelectric developments on the Wabash River.

The tributaries of the main rivers within or near the coal areas are generally too small and too flat for hydroelectric developments. In fact, the river gradients are so small that gravity flow would not be possible from the reservoirs to the assumed synthetic liquid fuels plant sites in any of the Areas. Water power generation in conjunction with proposed flood control reservoirs in Illinois is not likely. The proposed reservoirs in the Illinois River basin do not have much surplus storage capacity over that required for flood control, and some of the surplus is required for water supply. The proposed reservoirs in the Kaskaskia River basin might have some surplus storage capacity for power, but the Corps of Engineers in 1940 did not consider development of hydropower then economically attractive because of the low head available and because of the availability of coal for power in the immediate vicinity.

Water Rights

The common law doctrine of water rights is applicable to the surface and ground waters in Illinois. The common law doctrine for surface waters, also termed the riparian rights doctrine, accords to each owner of land contiguous to a stream the right to make whatever use of the water he requires for domestic purposes and the watering of livestock, and to make such use of the water for irrigation or other purposes (such as manufacturing) as is reasonable with regard to like reasonable uses by all other owners of land riparian to the same stream.

The common law, or old English law, for ground waters is based upon the principle that the owner of land is also the owner of all water underlying his realty. The land owner is thereby entitled to withdraw such subsurface waters without hindrance and regardless of the effect such withdrawal would have on surrounding territory.

At present, Illinois has no regulations controlling the utilization of surface waters, although permits from the Department of Public Works and Buildings are required for any construction, including dams, on any streams of the State. Similarly, there are no regulations controlling utilization of ground waters except that Illinois statutes do require that permits be obtained for drilling water, oil, and gas wells. The Department of Mines and Minerals issues the permits and submits copies for record to the Illinois Geological Survey. Well drillers are required to submit well logs to the Survey.

There are no State agencies that have the power to restrict the extraction of water by any parties. The Illinois Commerce Commission, however, in the interest of public water utilities subject to its control, can control the method of water development by requiring efficient production of water.

The State Water Resources and Flood Control Board serves as a general coordinating agency while the State Water Survey Division of the Department of Education and Registration provides the technical and research services in the State.

The Illinois State Department of Public Health maintains supervision over the adequacy of public and private water supplies, and plans for such works must be submitted to the Department. This authority extends to industrial drinking water supplies only when they are part of the public supply.

Water Available for Synthetic Liquid Fuels Development

The sources and quantities of water available for each of the General Areas of Coal Availability are summarized in Exhibit No. 18. This summary indicates where the water might be obtained for a unit 10,000-barrel-per-day plant, or for the ultimate development of all of the coal resources in the General Area. In some instances, a local source would be adequate for one or more plants, but the complete development of the coal resources would make it necessary to go to a more remote source of supply. The exhibit is arranged to show the local sources and the sources outside of the General Area.

The quantity of water available, noted in Exhibit No. 18, is the quantity actually needed for the ultimate fuels production that the coal resources would support, assuming that the synthine process was used throughout. The total water required for this ultimate production would be 3,734 cfs. This is only a small fraction of the total amount of water available in the coal-bearing area, and much larger quantities could be developed if necessary, although probably at substantially greater cost, by the construction of storage reservoirs to maintain adequate low-water flows.

The probable sources of water for synthetic liquid fuels plants in the various General Areas are summarized in the table below.

Summary of Probable Sources of Water for Synthetic Liquid Fuels Plants in Illinois

Source of Water Supply	Number of Plants or 10,000-barrel Units Supplied by Each Source: For Single 10,000-barrel Development in Each General Area	For Ultimate Development of the Coal Resources in Each General Area
Mississippi River	5	73.2
Illinois River	5(A)	28.3
Ohio River	2	16.2
Wabash River	1	3.6
Impounded Tributaries	18	63.1
Total	31	184.4

Note: (A) In the Marshall General Area a unit plant is assumed; however, using the synthine process, sufficient coal is available for only 8,000 barrels per day.

The first column indicates the probable source of water for synthetic liquid fuels plants in Illinois. The second column shows the distribution of one 10,000-barrel-per-day plant was built in each of the 31 General Areas. The third column shows the distribution that might be expected if all of the coal resources which are estimated adequate for the development of 1,844,000 barrels per day were actually used simultaneously for synthetic liquid fuels plants. For much more likely developments of size ranging between the two extremes noted, the individual General Areas must be considered to determine the most probable source of water.

A more detailed discussion of the availability of water for synthetic liquid fuels plants' supply from these sources is presented in the following paragraphs. Data concerning suitable reservoir sites are shown on Exhibit No. 19.

Mississippi River. Water developments for one 10,000-barrel-per-day synthetic liquid fuels plant in each of the five General Areas that would logically be served from the Mississippi River would require a total of 101 cfs of water. This quantity could be diverted from the Mississippi River without any noticeable effect on navigation.

Full development of the coal resources in Illinois would require 1,482 cfs from the Mississippi River. This quantity could normally be obtained without harmful effects upon navigation. However, during severe drought conditions, it would be necessary to supplement the low flows of the river from storage reservoirs in an amount equal to the synthetic liquid fuels plants requirements.

Illinois River. The Illinois Sanitary Water Board has indicated its objection to the removal of substantial quantities of water from the Illinois River above the Peoria-Pekin Area because of the effects on already serious local pollution. However, water for a single unit plant in any of the five General Areas that could be served from the Illinois River could be obtained without serious effect upon this pollution, and it would not be necessary to construct storage reservoirs for low-flow supplementation.

Complete development of coal resources for the production of synthetic liquid fuels in the area above Peoria would require the diversion of 117 cfs from the Illinois River. Such a withdrawal would have reduced the waste dilution there by approximately 5 percent during the low flow of September 1, 1945. If there should be local objection to reducing the amount of water available for diluting wastes at Peoria, storage reservoirs would be needed to supplement the low flow. Suitable reservoir sites are available, and data concerning some of those are shown in Exhibit No. 19.

In estimating the volume of storage required for synthetic liquid fuels water supply systems, it has been assumed that the low flows of the Illinois River would be supplemented whenever the natural flow at the Kingston Mines gage below Pekin was less than the control flow of 4,500 cfs.

Storage requirements to supplement the low flows in the Illinois River were calculated on the basis of the runoff record for the Vermilion River during the 1939-41 drought period. The runoff records for the Illinois River itself were not used, because they are affected by the diversion of water from Lake Michigan. The rainfall in both basins and natural runoffs of the Vermilion and Illinois Rivers are comparable. The quantity of storage required to supplement low flows in the Illinois River is shown on Exhibit No. 19A.

Ohio River. Maximum development of the coal resources in the Saline and Williamson Areas would require 328 cfs, or 3 percent of the Ohio River low flow. An appropriation of this magnitude would have very little practical effect on navigation or on the concentration of wastes in the Ohio River along this stretch of the river. It is assumed, therefore, that even if the full 328 cfs were required for the Saline and Williamson Areas, construction of storage reservoirs for supplementing low flows of the Ohio River would not be necessary.

Wabash River. Complete development of the coal resources in Illinois that would logically be served by the Wabash River would require 73 cfs. This requirement would cause no difficulty in the lower reaches of the Wabash River since pollution is not serious and the river is not used for navigation to any great extent.

Impounded Tributaries. The water requirements for single unit synthetic liquid fuels plants in 18 General Areas in Illinois would probably be obtained from tributary streams of the four large rivers. Since the minimum flows of these streams are not adequate to provide for existing uses and the additional demands of unit synthetic liquid fuels plants, it is necessary to provide storage reservoirs for low-flow regulation on the streams that would serve such plants.

Estimates of the amount of storage required to regulate stream flows for synthetic liquid fuels plants water supply are based on mean monthly runoff in terms of cfs per square mile of drainage area, as obtained from appropriate U.S. Geological Survey Water-Supply Papers. Where records are not available for the stream in question, flow records for adjacent and similar streams have been used. The total flow from any particular drainage area is assumed to be the area of the drainage basin above the proposed dam site times the average runoff per square mile.

The maximum quantity of water that can be developed in any drainage basin is the mean flow. Actually, there are always some losses such as evaporation and deep seepage, and it is rarely economical to build sufficient storage capacity to regulate the flow completely. The total quantity of water that can be developed practically in most parts of Illinois was found to be 0.3 cfs per square mile of drainage area. This estimate is based upon the assumption that a reservoir should not be drawn down during a drought period for more than two and one-half years before it is refilled.

In order to develop 0.3 cfs per square mile the storage required was found to be between 230 and 265 AF per square mile of drainage area or 15,000 to 18,000 AF for a single unit synthetic liquid fuels plant.

To these storage figures must be added allowances for evaporation and deposition of silt. Evaporation has been calculated at the rate of 48 inches over the drought period applied to the area of the reservoir at two-thirds capacity. While it is recognized that the quantity of silt is proportionately greater from small drainage areas than from large drainage areas, silt deposition in the reservoirs has been estimated at the rate of one-half AF per square mile of drainage area per year, or a total allowance of 20 AF per square mile of drainage area for a 40-year period.

The storage required to provide water for synthetic liquid fuels has been estimated from stream flow records collected by the USGS. The monthly mean flows at 19 gaging stations with records at least of 10 years and some as long as 37 years in the vicinity of the General Areas of raw material availability, were tabulated, and the average for the period of record was determined for each. (The gaging stations from which records were used are listed on Exhibits Nos. 13 and 14.)

Mass diagrams for the entire period of record were prepared for six of these stations in different parts of the State. From these it was found that the worst drought conditions were experienced in the years 1930-1933 and in 1939-1942. The longest continuous record for Illinois streams dates from 1915, but a 68-year record of the Mississippi River at Keokuk dating from 1878 indicates that the most severe drought occurred during the 1930-1934 period, and that the next most severe was the 1894-1896 period, followed by the 1939-1941 drought. It is reasonable to assume, therefore, that the drought period used in the calculations was as severe as any that has occurred during a 70-year period.

Five representative stations were selected for detailed study. These are tabulated below:

Gaging Stations for which Storage Yield Curves Were Prepared

River	Gaging Station	Drainage Area (Sq Mi)	Years of Record	Mean Annual Flow (Cfs per Sq Mi)
Big Muddy	Plumfield	753	34	0.907
Kaskaskia	Vandalia	1,980	37	0.738
Sangamon	Oakford(A)	5,120	11	0.620
Spoon	Seveille	1,600	32	0.619
Embarrass	Ste.Marie	1,540	34	0.775

Note: (A) Used in preference to longer record at Monticello, because flows at Oakford were relatively lower in drought periods.

Storage required to maintain specific yield was determined from mass diagram analysis for the critical low flow periods. In preparing mass diagrams the 90 percent or control flow was deducted from the natural stream flow to allow for downstream water rights. An adjusted mass diagram and the storage yield curve for one of these sections are shown in Exhibit No. 19B.

Many of the reservoir sites noted in Exhibit No. 19 have been inspected in the field. Construction of reservoirs at these sites appears practicable and would involve no excessive land cost. Detailed surveys and subsurface investigations would, of course, be needed to determine finally the suitability of each of the sites. While some of the reservoir sites selected might have to be eliminated, it is reasonable to believe that the over-all development could be carried out substantially as indicated. It is believed that a detailed field investigation might reveal additional feasible sites in areas for which topographic maps are not available.

Investigations indicate that some storage might be made available for synthetic liquid fuels developments in several of the reservoirs which have been proposed by the U.S. Corps of Engineers. Data concerning these proposed flood control reservoir projects are shown on Exhibit No. 20.

Relation of Water Needs for a Major Synthetic Liquid Fuels Development to Water Available in the Ohio River Basin

There are eight states having sufficient coal reserves in the Ohio River basin for a synthetic liquid fuels development. While it is unlikely that a large-scale development using all of the coal resources would take place throughout the Ohio Valley, it is important to consider the effect of large drafts of water upon the flow of the river. The Ohio River basin states, principal rivers and coal areas are shown in Exhibit No. 21.

Inventories of coal resources prepared for this report indicate that if all coal were devoted to the production of synthetic liquid fuels, the maximum water demand in the Ohio River basin states would be about 15,000 cfs. It is estimated that of this 15,000 cfs about 10,000 cfs would be obtained from water-supply systems involving storage reservoirs built either for the development of low-streams flow or for the regulation of low flows in the major tributaries. Reservoirs proposed for synthetic liquid fuels development would not reduce the low flows in the Ohio River as they would not store water during the critical low-flow period. The total amount of water to be pumped directly from the Ohio River or its major tributaries would be approximately 5,000 cfs. This would be taken throughout the length of the river. Withdrawal of this amount of water would affect the flow of the Ohio River, which is shown in the following table only to a small degree.

Average Flows of Ohio River at Three Points

Gaging Station	Drainage Area (Sq Mi)	Mean Flow (Cfs)	Years of Record
Sewickley, Pa.	19,500	31,896	1933-48
Huntington, Va.	55,900	76,450	1934-47
Louisville, Ky.	91,170	110,300	1929-47

The low flow of the Ohio River below Huntington would not be affected seriously by the withdrawal of this water but in the area above Huntington, where an estimated 3,000 cfs would be diverted, the low flow could be seriously affected.

The lowest flows of record occurred during the 1930 drought period. Unfortunately, the U.S. Geological Survey stream flows for this period are meager. However, it is possible to prepare, from the records of tributary streams and from the Corps of Engineers data regarding flows at Louisville, an estimate of the flow during October 1930, the lowest month of record. This runoff is plotted on the bottom line of Exhibit No. 22. Since the drought period of 1930, several reservoirs have been built in the Ohio River basin to conserve runoff and aid regulation. The more important are Tygart in West Virginia, Youghiogheny and Pymatuning Reservoirs in Pennsylvania, and Berlin and Mosquito Creek Reservoirs in Ohio; and a large number of reservoirs on the Tennessee and Cumberland Rivers. It is estimated that low flows of the Ohio River during 1930 in the critical section between Pittsburgh, Pa., and Huntington, W. Va., would have been increased by at least 1,000 cfs and the flow in the lower Ohio would have been increased 2,000 cfs if these reservoirs had been in use at that time. The middle line on Exhibit No. 22 indicates what the 1930 flow would have been with the regulation of these reservoirs.

Additional storage reservoirs for the regulation of the Ohio River flows are being considered. Some of these would be for flood control and river regulation and some for hydroelectric power production. The largest of these are the Allegheny in Pennsylvania, Mill Creek on Clarion River, Cave Run on Licking River in Kentucky, and several reservoirs on Green River in Kentucky. Some of these have been authorized for construction by Congress but no funds have been appropriated. If all the proposed reservoirs should be built, together with those already constructed, it is estimated that the minimum flow of the Ohio River in a period like 1930 would have been increased 5,000 cfs in the section above Huntington and 11,000 cfs near the mouth. The top line on Exhibit No. 22 indicates this increased runoff.

The Ohio River is not only an important waterway for freight haulage but it is also the source of water supply for some 30 communities drawing 300 cfs for domestic use and for many industries. Therefore, the quality of Ohio River water is of great economic importance. Many of the industrial uses are for cooling only and the water is returned to the river without much change except for a rise in temperature. Most of the water used for municipal purposes is returned as sewage. This stream pollution is most severe and the low flows most critical immediately below Pittsburgh. Serious pollution occurs also at Cincinnati, Louisville, and Evansville and it is important that the low flows be controlled at levels sufficient to prevent further degradation in quality.

It cannot be predicted now how many of these reservoirs will be built nor how much of the storage water will be available for the production of synthetic liquid fuels. However, the low-flow regulation program is primarily for the benefit of municipal and industrial water supplies in the Ohio River Valley and it is reasonable to believe that a large-scale synthetic liquid fuels development would have such economic importance that it would partici-

pate in any such program. Up to the present time, flood control and regulating reservoirs have been built with Federal funds and the municipalities and industries benefiting have not been asked to contribute.

If none of the reservoirs proposed for regulating storage capacity on the Ohio River were available to the synthetic liquid fuels industry, it would then have to provide its own reservoirs. The additional storage requirements needed to regulate the river above Huntington for maximum synthetic liquid fuels development would be that storage required to maintain a draft of 3,000 cfs and has been estimated at 1,200,000 acre-feet. These estimates are based upon gross water requirements for the synthetic liquid fuels plants and do not take into consideration the return water from the plants, amounting to more than 30 percent of the total demand. This return water would have a relatively high mineral concentration but none the less would add very substantially to the minimum flows.

The cost of providing this storage for over-all regulation of the Ohio River for full synthetic liquid fuels production has not been estimated. In any event, the cost would be spread out over so many plants that it would increase by only a very small amount the unit cost of water.

Water Resources Bibliography

Principal references consulted for this section as well as for a subsequent section pertaining to water supply are listed in a Water Resources Bibliography, Exhibit No. 23.

General Areas of Coal and Water Availability

In view of the foregoing discussions with respect to water, it appears that each of the 31 General Areas of Coal Availability previously established and shown on the map, Exhibit No. 11, will have available water sufficient for at least one 10,000-barrel-per-day synthetic liquid fuels plant and that consequently all 31 Areas in question may be classed as General Areas of Coal and Water Availability for the purpose of this report.

PART V

SUITABILITY OF GENERAL AREAS

COAL

General Areas of Coal and Water Availability

The 31 Areas of Coal and Water Availability in Illinois, which for convenience are numbered from 1 to 31 as shown in the following table, may be variously referred to herein either by number or name.

General Areas of Coal and Water Availability

Number	Name
1	Southeastern Grundy
2	LaSalle-Grundy
3	Bureau-Putnam
4	Henry No. 6
5	Northern Knox
6	Marshall
7	Peoria
8	Fulton-Knox
9	Vermilion
10	Logan
11	Macon
12	Menard
13	Sangamon
14	Northern Christian
15	Southeastern Montgomery
16	Macoupin
17	Madison
18	Bond
19	Clinton
20	Marion
21	Clay
22	Wayne
23	Jefferson
24	Washington
25	St. Clair
26	Randolph
27	Perry
28	Franklin
29	Jackson No. 5
30	Williamson
31	Saline

These 31 General Areas were next studied in detail from an economic standpoint to ascertain their further suitability for synthetic liquid fuels plant supply. The largest General Area is underlain by approximately 645 square miles of coal reserves. Available information indicates that sufficient quantities of coal are recoverable in each General Area to support one or more 10,000 barrel-per-day plants over a period of 40 years, of which 20 years' supply is from primary reserves and the additional 20 years' supply from either primary or secondary reserves. In all General Areas the total reserves, or very large proportions thereof, are recoverable only by underground mining. Five of the thirty-one General Areas are estimated to contain strippable deposits of varying amounts, but there are sufficient strippable reserves in only three General Areas to support a unit synthetic liquid fuels plant for the specified 40-year period.

As previously mentioned, the locations of the General Areas are indicated on Exhibit No. 10. Detailed coal production costs are shown in Exhibit No. 24. Basic data on coal bed characteristics, estimates of recoverable reserves, estimated capital cost requirements, and estimated cost of coal supply per barrel of synthetic liquid fuel final products, are summarized in Exhibit No. 25. The bibliography is presented as Exhibit No. 4.

Coal Characteristics and Properties
(See Exhibit No. 4 for references below)

Rank and Chemical Analysis. Descriptions and evaluations of the chemical and physical characteristics of the coal reserves in the 31 General Areas are generally available. These reserves, located in four principal coal beds, vary in rank from high-volatile A bituminous (Hvab) to high volatile C bituminous (Hvcb) with rank generally increasing from north to south within the coal-bearing area. Ranges in selected items of representative analyses of the beds containing coal reserves in the 31 General Areas are as follows (as-received basis):

(References: 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 15, 17, 19, 21, 22)

Representative Analyses of Coal Reserves
Face Samples (as-received basis) in the 31 General Areas

Coal Bed	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Bed No. 7 (1 General Area only)	14.2%	10.4%	2.8%	10,910
Bed No. 6:				
Maximum	18.5	11.8	4.2	12,580
Minimum	4.3	8.7	1.3	9,750
Bed No. 5:				
Maximum	15.4	11.1	4.5	12,610
Minimum	4.5	8.7	2.6	10,420
Bed No. 2:				
Maximum	17.1	8.6	4.9	11,340
Minimum	13.7	5.1	1.6	10,900

Detailed analyses and other characteristics of the coals in each General Area are presented in Exhibit No. 9 of this report.

Type and Petrographic Analysis. The Bureau of Mines has published results of petrographic assays on several representative Illinois coals in percentages as follows:

Petrographic Assays on Illinois Coals

County	Coal Bed Number	Anthraxylon	Translucent Attritus	Opaque Attritus	Fusain
Grundy	2	80	16	2	2
Gallatin	5	67	21	7	5
Sangamon	5	72	21	6	1
Franklin	6	70	24	1	5
Fulton	6	77	17	4	2
Macoupin	6	75	16	3	6
Perry	6	73	16	4	7

These analyses indicate that the coal is of the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain being present in minor amounts. Since all of the coals in the 31 General Areas of Illinois are closely similar in rank and in visual and chemical composition to the above coals for which petrographic analyses are available, there is no reason to expect any substantial differences in the

degree of heterogeneity or adaptability to hydrogenation of the Illinois coals.

The value of petrography in predicting hydrogenation yield lies in the fact that the degree of heterogeneity of lithologic components is readily indicated and the approximate proportion of high-carbon opaque constituents (difficult to liquefy) are revealed, whereas chemical analysis represents only the average composition of unlike components existing in undetermined proportions in the sample.

Organic and Inorganic Sulfur Content. The publications of the Illinois Geological Survey contain relatively comprehensive information on organic and inorganic sulfur contents of representative Illinois coals. Representative sulfur analyses for beds containing coal reserves in the 31 General Areas are as follows (as-received basis):

Analyses for Sulfur of Illinois Coals

Coal Bed	Sulfur Content (Percent) Total	Pyritic	Organic	Percent Organic to Total Sulfur
Coal No. 7	3.6%	1.8%	1.8%	50%
Coal No. 6 (southern)	1.4	0.8	0.6	43
Coal No. 6 (other than southern)	4.4	2.5	1.9	43
Coal No. 5 (southern)	2.6	1.7	0.9	35
Coal No. 5 (other than southern)	4.0	2.0	2.0	50
Coal No. 2	4.1	2.8	1.3	32

The above analyses indicate that organic sulfur, which is not considered amenable to reduction by mechanical cleaning, may range from 32 to 50 percent, averaging approximately 42 percent of the sulfur content in the various coal beds. The complete removal of pyritic (inorganic) sulfur by mechanical cleaning of the coal, if possible, would thus result in decreasing the total sulfur content by an average amount of approximately 58 percent. Thus, the minimum sulfur content would be reduced to the organic, of from 0.6 to 2.0 percent in the cleaned coal. The actual extent of reduction, however, depends upon the amounts, sizes, and types of occurrences of the pyritic sulfur-bearing ingredients in the raw coal. Further study of these coals is necessary, accordingly, to evaluate the reduction in total sulfur which might result from mechanical cleaning.

Storage, Weathering, and Slacking Characteristics. The high-volatile A, B and C bituminous rank coal reserves in the Illinois General Areas are similar to other coals of equal rank in weathering and slacking characteristics and present no particular storage

problems. These coals usually do not slack readily or ignite spontaneously when exposed to air. Surge storage at the mines will be necessary in synthetic liquid fuels manufacture, because of the probable fact that the mines will operate only two shifts per day for five days each week, while the synthetic liquid fuels plant will operate three shifts per day throughout the year. It is probable that substantial additional storage facilities will be necessary at the plant to protect the plant from interruptions or decreases in production at the coal mines, and from possible transportation stoppages between mine and process plant. As only commercially cleaned coal will be stored in volume, no especial hazards are expected, and the coal may be stored in necessary quantities for indefinite periods. Costs of surge storage at the mine, together with those of handling the coal into and out of storage, are provided for in the estimates of mine capital investment and mine production costs hereinafter established. At the process plant, provision is made for sufficient storage to provide a 30-day reserve supply and the costs of facilities for such storage and of their operation are included in process plant costs.

Grindability and Friability. Information on grindability of the coals in the 31 General Areas in Illinois indicates that they are similar in grindability to comparable industrial coals and will respond without undue difficulty to fine grinding. It should be noted that the degree of ease with which a coal may be pulverized depends not only on its relative grindability index, but also upon the fineness of grinding desired, and on its moisture content. The standard of grindability (Hardgrove index 100) is arbitrarily selected, according to the American Society for Testing Materials, as represented by low-volatile run-of-mine bituminous coal from the Jerome Mine, Upper Kittanning bed, Somerset County, Pa. Coals of medium surface moisture content, such as those in Illinois, are average in nature and neither retard nor accelerate pulverization due to coherence or tendency to form cakes.

The relative grindability indices of the coals in Illinois range between 48 and 74, or an average of 60. Available grindability data indicate that No. 2 coal ranges from 50 to 67 in grindability index with an average of 55, No. 5 coal from 54 to 72 with an average of 61, and No. 6 coal from 48 to 74 with an average of 63. No grindability index is available for the No. 7 coal. These relatively low index numbers indicate that the coals in the General Areas of Illinois resist pulverization to a greater extent than the standard coal, requiring an increase in pulverizer capacities which results in an increase in cost of pulverization over that of coal with an index of 100.

In addition to grindability, the comparative ease of crushing varies directly with the friability of the individual coals. Information on the friability of Illinois coals indicates that they are comparable to other high-volatile bituminous coals in this characteristic.

Nature of Partings. The available information on Illinois coal bed characteristics indicates that the majority of the beds

commonly contain one or more bedded impurities or partings. These partings, ranging from less than one-half inch to three inches in thickness, normally consist of shale or underclay, with varying admixtures of carbonaceous material. The partings are frequently pyritized in areas of local extent.

The No. 7 (Danville) bed of Vermilion County is generally uniform in thickness and physical characteristics within the area of occurrence. This bed does not contain a persistent parting but is characterized by the occurrence of frequent interbedded lenses of shale or pyrite, ranging up to two inches in thickness. Both roof and floor of this bed are composed of relatively "weak" material, fragments of which may become mixed with the raw coal during mining.

The No. 6 bed is characterized throughout Illinois by the presence of a persistent shale parting known as the "blue band" which normally occurs from one to three feet above the base of the coal bed, with thicknesses ranging from one-half to three inches. A second shale parting, occurring from two to four feet above the "blue band", frequently serves to divide the coal bed into three well-marked benches. Coal No. 6 in northwestern, central and southwestern Illinois, also contains frequent lenses of shale or pyrite which range up to one inch in thickness. The three benches are generally free from such lenses in southern Illinois, where a portion of the top coal bench is commonly left in place to serve as roof support. The roof of the No. 6 coal, elsewhere than in southern Illinois, ranges from a strong shale or limestone in southeastern Illinois to a very weak "clod" or "white-top" type of shale in northwestern Illinois.

The No. 5 bed is typically free of persistent, interbedded partings, especially in southern Illinois, where the No. 5 and No. 6 coals have long constituted the highest-quality coals in the State. Coal No. 5 in central and northwestern Illinois, however, is relatively high in ash, derived from shaly material which was deposited in disseminated form through the coal bed, rather than in the form of distinct partings. The No. 5 bed of central and northwestern Illinois is further characterized by the presence of numerous vertical shale partings, which commonly transect the coal bed at intervals of from less than fifty to several hundred feet. These partings, known as "horsebacks", usually occur in two sets of intersecting parallel lines, which divide the coal bed into diamond-shaped blocks. The horsebacks, range from a few inches to as much as two feet in width and must be handled during the mining operation. The roof material overlying coal No. 5 in central and northwestern Illinois normally consists of a strong, black "slate", which characteristically contains large ovoid concretions known as "niggerheads". These concretions frequently come down without warning and add to the difficulty of roof support.

The No. 2 bed does not contain any persistent, bedded partings and is generally uniform in thickness and physical characteristics within the areas of occurrence. Both roof and floor of

this bed are composed of relatively "weak" material, fragments of which may become mixed with the raw coal during mining.

Mechanical Cleaning. In considering washability characteristics, the character, number, and thickness of contained partings serve as a partial guide to the relative ease or difficulty with which a specific coal may be mechanically cleaned. While the presence of partings in Illinois coals is generally not such as to seriously interfere with mining operations, they do affect the type and capacity of the necessary cleaning facilities and the amount of refuse which must be handled during the cleaning process. These factors were taken into consideration in estimating mine investment and operating costs in each of the General Areas as hereinafter established.

Relatively extensive data on washability characteristics and performance of Illinois coals are available from studies by the Illinois Geological Survey, the Department of Mining Engineering, University of Illinois, and the Bureau of Mines. These data indicate that Illinois coals are generally amenable to improvement in quality by commercial-type mechanical cleaning. With installation of relatively simple facilities for removal of solid impurities and other high-ash refuse, the average cleaned coal products from the various General Areas should contain the following approximate ash and sulfur contents (as-received basis):

Estimated Ash and Sulfur Contents for
Average Cleaned Coal Products from Various General Areas

	Ash (Percent)	Sulfur (Percent)
Bed No. 7	8.5%	2.5%
Bed No. 6:		
Maximum	10.0	3.0
Minimum	7.0	1.0
Bed No. 5:		
Maximum	10.5	3.0
Minimum	8.0	2.0
Bed No. 2:		
Maximum	7.5	3.0
Minimum	5.0	1.5

Available information indicates that mechanical cleaning of Illinois coals, in addition to reduction of ash and sulfur, also reduces the proportion of opaque lithologic constitutents in the raw coal, thus improving amenability to hydrogenation. Information on the specific quality of the cleaned coal resulting from mechanical preparation in each General Area, however, requires further washability investigations of typical samples of the available coal reserves.

The foregoing discussion of washability of Illinois coals applies only to the preparation of raw coal from the available reserves to a merchantable quality, as would be done in ordinary commercial practice. The possibilities of further reduction of ash, sulfur, and opaque constituents for purposes of hydrogenation require additional study beyond the scope of this phase of the synthetic liquid fuels survey and are not herein considered.

Modern mechanical mining, because of its lack of selectivity at the working face, requires mechanical cleaning facilities to obtain economic production costs. Mechanical cleaning also insures the removal of solid impurities which might otherwise severely damage pulverizers or other synthetic liquid fuels plant equipment. Provision is made in the estimates of capital and producing costs, hereinafter established, for a mechanical cleaning plant designed simply to remove solid and high-ash impurities from the mine-run coal in each of the General Areas. There is no indication that such cleaning would present any unusual problems or require abnormal expenditures in any of the General Areas.

Mine Waste Disposal. The refuse from the coal preparation plant at the mine is estimated to consist largely of shale partings and contaminating material from roof or floor, together with some bone and fusain from the coal bed. According to the Bureau of Mines Mineral Industry Surveys, Bituminous Coals and Lignite in 1948, the ratio of refuse to raw coal which was cleaned was 15.6 percent in Illinois in that year. It is estimated that approximately 25 percent of the coal cleaned came from the No. 5 bed and 75 percent from the No. 6 bed. These two beds accounted for a total of approximately 95 percent of all coal produced in Illinois in 1948. On the basis of 15.6 percent of refuse from the total raw coal moved to cleaning plants, the estimated percentage of refuse to clean, marketable coal would be 18.5 percent. The estimated range of percentage of waste to marketable coal in the various General Areas would be from approximately 12 to 25 percent. At 25 percent of average daily production of marketable coal (6,760 tons per mine working day for all 31 General Areas in Illinois), the refuse would total approximately 1,690 tons per mine working day, or 405,600 tons per year, equivalent to 270,400 cubic yards, based on supplying marketable coal to a hydrogenation plant; and approximately 2,173 tons of refuse per mine working day, or 521,520 tons per year, equivalent to 347,680 cubic yards, based on supplying marketable coal to a synthine plant.

The disposal of this type and quantity of refuse presents no particular problems. It could be transported by tramway or by trucks from the preparation plant to nearby mine property, or to selected areas of rugged land or other land unfit for farm use, of which there are many acres in each of the General Areas. With proper precautions, the possibilities of contamination of water supply should be negligible. The estimated capital and operating costs hereinafter established in this report provide for waste disposal from the coal preparation plant, assuming that the waste-disposal tract is within three miles of the coal preparation plant.

Hydrogenation Yield. The degree of liquefaction of coals by hydrogenation is, roughly, inversely proportional to their moisture- and ash-free carbon content as determined by ultimate analysis. Coals with high-carbon content are generally low in liquefaction yield. Normal carbon contents (maf) range from approximately 55 percent in peat to 95 percent in anthracite. The coals in the 31 General Areas of Illinois range between 77 and 84 percent in carbon content (maf) with an average of 80 percent. This average is comparable to a carbon content of 80.6 percent (maf) for an assay on No. 6 coal from Franklin County, from which an oil yield of 60 percent of the coal as received was obtained. This yield compares with a high of 64 percent from a high-volatile A bituminous coal in Pennsylvania and with a low of 31 percent from a lignite in North Dakota. The coals in all Illinois General Areas are reasonably comparable in rank and quality to the No. 6 coal assayed by the Bureau of Mines, and a satisfactory hydrogenation yield may be expected from them, although the suitability of a particular coal for hydrogenation purposes can best be determined by actual tests.

Land Ownership, Coal Rights, and Surface Valuation

(See Exhibit No. 4 for references A below.)

Private Ownership and Purchase Costs. Essentially all coal-bearing lands in Illinois are privately owned. Costs of underground coal, considered on a lease or royalty basis, without surface rights, may amount to 5 cents or more per ton and, in areas of unusually favorable mining conditions or locations, may range up to 25 cents per ton. Minimum costs of strippable coal, on a similar lease or royalty basis, but including necessary surface lands, are probably not less than 10 cents per ton and, in areas of unusually favorable mining or agricultural conditions, or in especially favorable geographic locations, may range up to 50 cents per ton. Surface land values without coal rights range from $20.00 to $200.00 or more per acre, depending on the agricultural value and geographic location of the specific property.

Legislation Affecting Production of Coal

(See Exhibit No. 4 for references B below.)

Taxes. Real estate taxes in the cities and towns of Illinois outside of Cook County generally range from 2 to 3 percent (with an average of about 2.5 percent of assessed valuation, which is generally based on 100 percent of full cash value as determined by the local taxing officials and the State Department (Equalization Board) of Revenue. Taxes on personal property take the same rate.

(References A: 10, 12, 13, 14, 16)
(References B: 13, 20)

Coal lands held in reserve for mining by coal companies are assessed only for the normal tax as farm land, based on agricultural productivity. Other taxes, such as corporate organization and qualification fee, corporation franchise tax, and sales tax, are nominal and would not apply separately to coal mining if conducted as a captive operation with all production going to a synthetic liquid fuels plant. There is no State income tax. An effort has been made in recent years to tax strip mining, but the tax law was held to be unconstitutional.

Restitution of Surface Damaged by Mining. Illinois has no law requiring restoration of surface damaged by strip mining, although efforts have been made to enact such a law, without success. Damage by strip mining to public property such as roads, however, is usually repaired or replaced by the strip-mine operators. The Illinois Coal Stripping Association, in cooperation with the Illinois Agricultural Experiment Station, has been actively investigating the potential revegetation and utilization of strip-mined areas in Illinois as a means of protecting bird and wild life, enhancing the value of such lands for taxation, decreasing soil erosion, preventing pollution of rivers and streams, preventing combustion of unmined coal, and generally improving the use and enjoyment of such lands. The average potential cost of reclamation is estimated at $50.00 per acre.

There is no specific legislation covering damages resulting from subsidence caused by underground mining, but other existing laws would make the operator liable for damages to property of others if it could be proved that such damages were the result of underground mining. Estimated amounts for these contingent liabilities are included in the following estimated production costs.

Production Costs

(See Exhibit No. 4 for references below.)

The data on coal bed occurrences in the 31 General Areas are in nowise sufficient in scope or in detail to permit the preparation of actual layouts and of specific estimates of mining costs based thereon. Extensive drilling programs are necessary before precise location and extent of reserves available for mining operations can be determined. Comprehensive engineering studies, based on the results of the drilling programs, will then be necessary to determine the equipment and methods of mining best adapted to the efficient and economic production of fuel for synthetic liquid fuels plant supply. The estimates of coal production costs hereinafter presented are necessarily generalized in nature and are based on the assumption that thorough drilling and engineering will precede any development of mining operations in connection with coal supply for synthetic liquid fuels manufacture, thereby permitting more precise estimates of costs.

(References: 10, 12, 13, 14, 18,23)

In estimating over-all mining costs for each of the 31 General Areas in Illinois as of March 31, 1950, the total estimated investment costs are considered to include erection of all necessary mine structures, together with purchase and installation of all necessary operating equipment. They also include investment costs of facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, a mechanical cleaning plant designed largely to remove solid and high-ash impurities from the raw fuel, waste disposal from the preparation plant, sufficient coal surge storage at the mines to provide uniform daily shipments to the synthetic liquid fuels plant, engineering, development, and contingencies. While the estimated investment costs do not include purchase price of surface or coal lands, a royalty charge of $0.10 per ton of cleaned coal for underground mining and of $0.15 per ton of cleaned coal for strip mining, as included in producing costs, is considered to represent the cost of acquisition of coal reserves. In the case of strip mining, the royalty figure of $0.15 per ton is also considered to provide for the return of a portion of the cost of necessary surface acquisition, or its equivalent, through reclamation and re-use after strippable reserves are depleted.

In estimating producing costs for each of the 31 General Areas in Illinois, as shown on Exhibit No. 24, separate consideration was given to each of the following principal items of cost, their total being taken as the total producing cost per ton of cleaned coal:

(1) All labor. This item includes all labor costs paid in the form of wages for mining (pieceworkers and dayworkers) and for yardage and dead work and in the form of salaries paid to supervisory, technical, and clerical employes at the mines. Weighted average wage rates were calculated from the schedules of wages established by the National Bituminous Coal Wage Agreement of 1950 for the various mining districts, with suitable adjustment for the concentration of high-wage workers in a fully mechanized underground or stripping operation. The labor cost per ton was calculated by dividing the estimated weighted average daily wage rate by the estimated productivity in tons of cleaned coal per man-shift.

(2) Vacation payments. This item represents the vacation allowance of $100 per year to each employe, where applicable, and is computed by dividing $100 by the estimated annual production per man (240 days times productivity per man-shift). In actual practice, this may be increased slightly due to injured men or others carried on the payroll but not actually engaged in production.

(3) Welfare fund. This item represents a flat payment of $0.30 per ton which is paid into the U.M.W.A. welfare fund for each ton of coal produced for use or for sale in accordance with the National Bituminous Coal Wage Agreement of 1950.

(4) All supplies. This item includes the costs of all materials and supplies used in mining and in operating the mine equipment and facilities, including the maintenance and repair of mine structures and equipment. Additional included costs consist of freight, drayage, expressage, and storage of supplies, mine office supplies, fuels other than coal, and rentals of equipment. The costs of such supplies per ton, as estimated in this survey, average approximately $0.72 for underground operations, and $0.75 for stripping operations, the actual estimated amounts to some extent varying inversely with the estimated productivity per man-shift, but being modified in accordance with consideration of the anticipated natural mining conditions.

(5) Power. This item includes the cost of all power requirements at the mining operations, whether purchased from outside sources or produced by a mine-operated central power station. It also includes the cost of any coal required to produce heat at the mine. While small variations in cost of power may be expected to exist among the General Areas considered in this survey, an assumed cost of $0.15 per ton is herein employed for estimating purposes.

(6) Payroll taxes. This item includes the costs of social security (old-age benefits), unemployment taxes, and any other Federal or State taxes levied upon the amount of the payroll. These taxes average approximately 4 percent of the labor cost.

(7) Other taxes, insurance, miscellaneous. This item includes the following types of costs:

a. Real estate, personal property, and other taxes on mine property and equipment, including reserves. These taxes may range from 1 to 6 percent of the fair cash value of the property as established by the local assessors, depending on locality.

b. Corporate, privilege, and severence taxes which average approximately $0.02 per ton.

c. Workmen's compensation and vocational disease insurance, including the sums paid to an insurance company or to a State fund for protection of the employes, which aggregate approximately 5 percent of the payroll.

d. Other insurance such as fire, tornado, and other classes of insurance applicable to the mine property, which is estimated to average approximately $0.01 per ton.

e. Costs arising from unforeseeable and unpredictable conditions of all kinds which are herein estimated at a flat rate of $0.10 per ton. This item is added to the producing costs as estimated in this survey because of the limited available information on mining conditions in many of the General Areas.

(8) Depreciation. This item represents the cost of providing for replacement of the mining facilities and equipment at the end of their useful life. In determining producing costs the weighted average useful life of all items of mine property and equipment, exclusive of coal reserves, is estimated to be 15 years. The rate of depreciation, accordingly, is taken at 6.67 percent of the initial investment.

(9) Royalty or depletion. As discussed in a preceding paragraph, the estimated investment costs do not include the purchase costs of surface and coal properties. A royalty charge of $0.10 per ton of cleaned coal for underground mining and of $0.15 per ton of cleaned coal for strip mining is herein considered to represent the cost of acquisition of coal reserves.

(10) Engineering, management, administration. This item includes the costs represented by salaries and expenses of administrative, management, and engineering personnel, together with salaries of associated assistants, bookkeepers, clerks, and stenographers. It also includes legal expenses and office expenses, or rent, including depreciation on office equipment. The cost of this item is herein estimated at $0.10 per ton.

Detailed consideration of all factors pertinent to estimating the potential mine investment costs for each of the 31 General Areas indicated that the General Areas could be classified into four groups of relative mine plant and equipment capital costs, arranged in increasing order of investment costs as follows:

1. Below average. Saline, Jefferson, Jackson No. 5, Franklin, Williamson, Perry, Southeastern Grundy.

2. Average. St. Clair, Randolph, Madison, Marshall, Logan, Menard, Sangamon, Macoupin.

3. Above average. LaSalle-Grundy, Bureau-Putnam, Washington, Macon, Marion, Northern Christian, Southeastern Montgomery, Bond.

4. Highest cost. Vermilion, Clinton, Clay, Wayne, Peoria, Fulton-Knox, Northern Knox, Henry No. 6.

The maximum ranges in daily and annual synthetic liquid fuels plant and mine requirements for the production of 10,000 barrels of synthetic liquid fuels final products per calendar day in the several General Areas, based on 98 billion Btu per calendar day for the hydrogenation process and 126 billion Btu per calendar day for the synthine process, may be summarized as follows:

Range in Daily and Annual Coal Requirements of a Unit Plant

	Maximum Btu Value		Minimum Btu Value(A)	
	Hydrogenation	Synthine	Hydrogenation	Synthine
Average Btu Content of Coal (as received)	12,310	12,310	10,050	10,050
Tons per Day:				
Plant (365 working days)	3,981	5,118	4,876	6,269
Mine (240 working days)	6,054	7,784	7,416	9,534
Annual Requirements (thousands of tons)	1,453	1,868	1,780	2,288

Note: (A) Exclusive of strip coal with Btu of 9,930, the reserves of which are sufficient for only 11 years hydrogenation and 9 years synthine.

Although estimated total recoverable reserves in the 31 General Areas are sufficient to supply synthetic liquid fuels plants having a combined capacity of from 1,844,000 to 2,373,000 barrels a day for 40 years, depending on whether the synthine or hydrogenation process is used, the following estimates on coal production costs are based on the capacity of mine operations necessary to supply one 10,000 barrel-per-day unit synthetic liquid fuels plant in each of the General Areas.

Strip Mining Costs. Only the Northern Knox, Peoria, and Perry General Areas contain sufficient estimated strippable coal reserves to indicate extensive stripping operations of 40 years or over. Because of inherent limitations in uncovering capacity of single stripping units, and to minimize the effects of such hazards as failure of excavating, loading, or transporting equipment, it is assumed that mining in these three General Areas would be conducted in two separate pits from which coal would be handled through joint

facilities, including a central preparation plant, to the transportation system by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mines would be provided to assure continuous supply for year-round, three-shift-per-day operation of the synthetic liquid fuels plant from mines operating on a five-day-per-week, two-shift-per-day basis. In other General Areas, strip mining would probably be combined with underground mining for the most economic results.

Approximate capital investments required for 40 years' production of synthetic liquid fuels plant supply by strip mining in quantities cited hereinbefore are estimated as of March 31, 1950 at from $6,328,000 to supply a hydrogenation plant for 40 years in the Perry General Area, to $9,016,000 to supply a synthine plant in the Northern Knox General Area for 31 years. Factors affecting strip-mine investment costs are depth and character of the overburden and quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuels process in which the coal is to be used. The quality affects the type and capacity of preparation facilities necessary to produce a merchantable coal.

Actual producing costs for strip mines in Illinois have been relatively less than the average costs for the United States, these figures having been $2.10 per ton for the United States and $1.75 per ton for Illinois in 1945, according to Economic Data, Office of Price Administration, for that year.

An estimated over-all labor productivity in new operations, measured by the average tons produced per shift per man employed in the stripping operation and in necessary auxiliary facilities, may be partially based upon experience at present stripping operations because of their relatively high degree of mechanization and their relatively comparable capacity of output.

Bureau of Mines statistics on bituminous coal production in 1948 indicated that average productivity in stripping operations by counties ranges from 8.66 to 29.58 tons per man-shift, averaging 18.52 tons for the entire State. Assuming that the installation of modern high-capacity operations, including the purchase and use of large stripping shovels, draglines, trucks, and other modern equipment, would result in an estimated productivity of 20 tons per man-shift in average mining conditions, and of 25 tons in better-than-average mining conditions, the estimated costs of strip-mine production in the five General Areas containing strippable reserves, after making allowances for variations in preparation costs, range as follows:

Estimated Costs of Strip-mine
Production in Five General Areas in Illinois
(As of March 31, 1950)

General Area Designation	Btu per Pound (As received)	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Henry No. 6	9,930	20	$2.91	14.65¢
Northern Knox	10,200	25	2.68	13.14
Peoria	10,680	25	2.68	12.55
Randolph	10,940	25	2.58	11.79
Perry	11,305	20	2.95	13.05

Details of the above estimated costs for each General Area are shown in Exhibit No. 24. They are based on retirement of the property in 15 years and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 wage agreement.

These costs reflect the concept of most efficient application of present-day strip mining methods and equipment. Opportunities for possible future improvements of mining methods or equipment in areas similar to Illinois probably best await potential development of high-speed, high-capacity excavating, loading and hauling equipment. It is not possible at this time, however, to predict successful development and application of such equipment to Illinois coal reserves, or to estimate possible future saving in production costs which might accrue through their use.

Underground Mining Cost. Because of inherent limitations on transporting coal to the surface, and to minimize the possible effects of such hazards as mine fires, roof falls, floods, etc., it is assumed that the annual requirements in each General Area would not be obtained through a single opening. A minimum of from two to three underground mining operations would probably be opened at appropriate intervals in each Area for concurrent operation. Although obtained from separate underground openings, it is assumed that the raw coal would be handled through joint surface facilities, including a central preparation plant, to the transportation system by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mine would be provided to assure continuous supply for year-round, 3-shift-per-day operation of the synthetic liquid fuels plantfrom mines operating on a 5-day-per-week, 2-shift-per-day basis.

Approximate capital investments required for underground production of synthetic liquid fuels plant coal supply in the quantities previously cited are estimated as of March 31, 1950, at from $5,957,000 to supply a hydrogenation plant in the Saline General Area to $10,296,000 to supply a synthine plant in the Henry No. 6 General

Area. Factors affecting mine investment costs are depth and character of the bed and its associated strata, together with quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuels process in which the coal is to be used. The quality affects the type and capacity of preparation facilities necessary to produce a merchantable coal.

Actual producing costs for mechanical underground mining in Illinois have been relatively lower than average costs for the United States, having been $2.64 per ton for the United States and $2.03 per ton for Illinois in 1945, according to Economic Data, Office of Price Administration, for that year.

Estimated over-all labor productivity in new operations, measured by the average tons produced per shift by each man employed in the underground operation and in necessary surface facilities, can be based upon experience at present underground operations because of their relatively high degree of mechanization.

Bureau of Mines statistics on bituminous coal production in 1948 indicated that Illinois underground mines had an average productivity of 7.50 tons per man-shift. An estimate of future productivity per man-shift in new underground mines necessarily should take into account past records of productivity, but must recognize that older mines usually involve relatively long and costly haulage, and that the character of a particular seam, the mining conditions, and the type of equipment are all important factors affecting the productivity; likewise, if proposed mining operations involve new coal beds not now producing, estimates of productivity may be noticeably affected. The estimates herein for new underground mining operations are dependent on judgment based on consideration of all known factors, including Bureau of Mines data on average productivities in going operations. Assuming that the installation of modern high-capacity operations, including the purchase and use of all necessary mechanical equipment, would result in an estimated productivity ranging from 5 tons for very difficult conditions to 12 tons for better-than-average conditions, the estimated costs of production by underground operations in the 31 General Areas, after making allowances for variations in preparation costs, range as follows:

Estimated Costs of Production by New Underground Operations in 31 General Areas
(As of March 31, 1950)

General Area Designation	Btu per Pound (As received)	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Southeastern Grundy	11,130	5	$5.46	24.53¢
LaSalle-Grundy	11,070	5	5.48	24.75
Bureau-Putnam	11,040	5	5.48	24.82
Henry No. 6	10,050	7	4.46	22.19
Northern Knox	10,200	7	4.46	21.86
Marshall	11,300	5	5.48	24.25
Peoria	10,700	7	4.44	20.75
Fulton-Knox	10,450	7	4.44	21.24
Vermilion	10,910	7	4.44	20.35
Logan	10,750	10	3.58	16.65
Macon	10,700	10	3.58	16.73
Menard	10,730	10	3.58	16.68
Sangamon	10,660	10	3.58	16.79
Northern Christian	10,870	12	3.24	14.90
Southeastern Montgomery	10,760	12	3.24	15.06
Macoupin	10,740	12	3.23	15.04
Madison	10,750	9	3.81	17.72
Bond	10,800	9	3.83	17.73
Clinton	10,870	7	4.44	20.42
Marion	11,200	7	4.44	19.82
Clay	11,370	5	5.51	24.23
Wayne	11,440	5	5.51	24.08
Jefferson	11,980	9	3.81	15.90
Washington	11,000	9	3.83	17.41
St. Clair	10,980	11	3.39	15.44
Randolph	11,030	11	3.39	15.37
Perry	11,290	11	3.39	15.01
Franklin	11,830	11	3.39	14.33
Jackson No. 5	11,670	7	4.40	18.85
Williamson	11,910	10	3.58	15.03
Saline	12,310	10	3.58	14.54

Details of these estimated costs for each General Area are shown in Exhibit No. 24. They are based on retirement of the property in 15 years and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 wage agreement.

These costs reflect the concept of most efficient application of present-day underground mining methods and equipment. Opportunities for possible future improvements of mining methods or equipment in areas similar to Illinois best await potential development of (1) high-capacity loading equipment especially designed for longwall mining as practiced in the United Kingdom,

and (2) continuous mining machines which combine cutting, drilling, blasting, and loading operations now under scrutiny and development at a number of points in the United States. Both of these types of equipment are being actively tested, and if perfected, could result in changes in mining methods which would reduce the estimated producing costs in Illinois. It is not possible at this time, however, to predict the successful application of such equipment to Illinois coal reserves or to estimate possible future savings in production costs which might accrue through their use.

In considering possible revolutionary techniques in utilizing areas of coal reserves, the underground gasification of coal in place offers considerable potential promise since it would eliminate the relatively costly processes of mining the coal and gasifying the mined output in gas generators to produce synthesis gas. This method of utilization would also provide a low-cost fuel for power generation and would permit utilization of coal from beds which would otherwise be costly or uneconomic of operation. The results of experiments in underground gasification now in progress by the Bureau of Mines and the Alabama Power Company indicate that the process has distinct possibilities and is worthy of continued experimentation. It is not possible at this time, however, to predict the successful application of this method of utilization to the coal reserves in the General Areas in Illinois.

Coal Transportation. Provision is made in the capital and operating costs hereinbefore presented for transportation of coal from the several mine openings to a joint distribution point in each General Area for handling onto the transportation system by which the coal is delivered to the synthetic liquid fuels plant. As elsewhere indicated, it has been assumed for purposes of this survey that the site of the synthetic liquid fuels plant would be located within a three-mile radius of the mining operation. Under this assumption, no additional facilities or costs for transportation, other than that provided for in the estimates of costs already established, are contemplated.

Coal Supply from Present Operations. Bureau of Mines data on bituminous coal production in 1948 indicate that a synthetic liquid fuels plant in each of thirteen of the thirty-one General Areas could have been supplied with sufficient coal in that year to have produced synthetic liquid fuel final products at the rate of 10,000 barrels per day. Such consumption, however, would have required from approximately 15 to 100 percent of the total production of the counties in which or near which the 31 General Areas are located. For one unit 10,000-barrel-per-day synthine plant in each of the 31 General Areas, a total of approximately 64,665,000 tons of coal annually would have been required. This amount equals approximately the total State production in that year.

In Illinois, the 1948 total production of 65,342,089 tons was produced in 228 working days, an average of 286,588 tons per day. At such a daily rate, the additional coal which could have been produced during a 240-day work year would have amounted to 3,439,056

tons, sufficient for approximately 16,000 barrels of synthetic liquid fuel final products per day.

Accurate information on current costs of production at present operations in Illinois is not available. Consideration of all known factors of increased wage rates, costs of supplies, contributions to welfare funds, etc., since the last year of available cost data (1945) indicates that coal is now being produced in Illinois at costs ranging from approximately the equivalent of the estimated costs of mine operations as herein presented to as much as $0.75 per ton in excess of such costs.

Mine-run coal could probably be purchased from current operations at such costs ($2.58 to $2.95 per ton for strip coal and $3.23 to $5.51 per ton for underground coal) plus freight, plus $0.20 to $0.60 per ton for profit and income taxes. Selected sizes would probably run slightly higher in price, while it is possible that lower-priced sizes such as screenings could be purchased from current operations for production of synthetic liquid fuels, on a contract basis, at fob. mine prices comparable to or slightly less than the costs estimated herein. In general, such sizes would contain higher ash and sulfur contents than the cleaned mine-run products estimated as obtainable from reserves of the General Areas.

Based on operating cost data for the first quarter of 1946 (Office of Price Administration) for large mechanized mines, the Corps of Engineers, Department of the Army, has estimated the present cost of producing coal in four Illinois subdistricts, as follows:

Estimated Cost of Producing Coal
in 4 Illinois Subdistricts

	Fulton-Peoria		Central	Belleville		Southern	
Bed No.	6	5	6	6	6	6	5
Thickness (In.)	35-45	40-55	80-100	60-75	70-100	90-125	50-60
Type Mining	Strip	Strip	Und'g	Strip	Und'g	Und'g	Und'g
Productivity (A)	20	25	10	20	10	11	9
Estimated Costs(B):							
1st Quarter,1946	$1.45	$1.35	$1.60	$1.45	$1.80	$1.70	$1.85
Increase to 4/1/50	0.80	0.75	1.00	0.80	1.10	1.00	1.15
Total during March 1950	$2.25	$2.10	$2.60	$2.25	$2.90	$2.70	$3.00

Note: (A) Average output in tons per man-day
(B) Producing and administrative

The increases in costs per ton since the spring of 1946 reflect the 1950 U.M.W.A. wage agreement, ranging from $0.75 for strip mining of Fulton-Peoria No. 5 coal to $1.15 for underground mining of Southern Illinois No. 5 coal, and are based on $4.75 per day increases in wages; $25 per year increase in vacation

pay; 30 cents per ton welfare payment; 35 and 45 percent increases in supply costs for strip and underground mining, respectively; and 25 percent increase in all other costs.

The above costs are fob. tipple, excluding selling expenses, and represent large, modern, highly efficient and mechanized mines producing merchantable coal in sufficient quantities to meet the requirements of unit synthetic liquid fuels plants. However, they do not reflect improvements in coal mining techniques since 1946, including the continuous coal mining machines now being tested. The costs do not necessarily represent either the present average production costs for the entire subdistricts enumerated above, or the average potential production costs which might be obtained for new operations in the areas underlain by estimated reserves of the above coal beds, but probably represent the optimum mining operations within the area.

An additional cost of purchasing coal from present operations would be the transportation charges, or freight rates, from existing mines to the synthetic liquid fuels plant. Unless located in the heart of a group of substantial commercial operations, such additional costs for delivered coal would probably range from $0.60 to $1.50 per ton, depending on the selection of location of a synthetic liquid fuels plant.

Total Costs. Detailed studies leading to estimated capital and operating costs, as of March 31, 1950, based on information as to coal characteristics and available reserves, have indicated that considerable variations in costs exist among the several General Areas, partly because of differences in proportions of strippable reserves, where present, in the General Areas. Differences in estimated productivity due to varying mining characteristics, in varying degrees of amenability to mechanical cleaning because of the nature, thickness, and number of included partings, and in the inherent calorific value of the various coal beds at the locations in which reserves are available, also affect the extent of variations in costs between General Areas. Details of these estimates and of the coal data upon which they are based are provided in Exhibits Nos. 24 and 25.

Estimated initial capital costs range from $5,957,000 to supply a unit hydrogenation plant in the Saline General Area to $10,296,000 to supply a unit synthine plant in the Henry No. 6 General Area. These costs are based on provision for complete facilities for underground mining, conveying of raw coal to surface, transportation to central preparation plant, mechanical cleaning, including refuse disposal, and loading for shipment or into surge storage at the mine with subsequent reloading. In those General Areas where some of the coal may be produced by strip mining, the initial investment would be somewhat less, but the ultimate total investment during the 40-year period would be about the same as for all-underground mining operations, since the underground facilities would have to be ready for capacity production before the strippable reserves were fully depleted. In some General Areas, strip and

underground operations would start simultaneously and operate concurrently. The salvage values of the stripping and coal-loading equipment for the strip operations should be approximately sufficient to offset the required added investment for equivalent underground facilities; this would tend to bring the net total up to, but not more than the figures used in this report for estimated mine capital costs. The estimated capital costs are summarized as follows:

Initial Capital Costs for Unit Plant Coal Supply
in Thousands of Dollars
(As of March 31, 1950)

General Area Designation	Hydrogenation			Synthine		
	Underground	Strip	Ultimately (Combined)	Underground	Strip	Ultimate (Combine
Southeastern Grundy	$6,428		$6,428	$ 8,264		$ 8,26
LaSalle-Grundy	6,783		6,783	8,723		8,72
Bureau-Putnam	6,804		6,804	8,749		8,74
Henry No. 6	8,010	$6,484	8,010	10,296	$8,338	10,29
Northern Knox	7,889	7,012	7,889	10,143	9,016	10,14
Marshall	6,649		6,649	8,547		8,54
Peoria	7,185	6,700	7,185	9,241	8,612	9,24
Fulton-Knox	7,357		7,357	9,464		9,46
Vermilion	7,048		7,048	9,064		9,06
Logan	6,656		6,856	8,556		8,55
Macon	6,851		6,851	8,811		8,81
Menard	6,668		6,668	8,572		8,57
Sangamon	6,712		6,712	8,628		8,62
Northern Christian	6,909		6,909	8,887		8,88
Southeastern Montgomery	6,980		6,980	8,975		8,97
Macoupin	6,660		6,660	8,564		8,56
Madison	6,656		6,656	8,556		8,55
Bond	6,955		6,955	8,942		8,94
Clinton	7,074		7,074	9,099		9,09
Marion	6,867		6,867	8,828		8,82
Clay	7,079		7,079	9,099		9,09
Wayne	7,034		7,034	9,045		9,04
Jefferson	5,972		5,972	7,680		7,68
Washington	6,829		6,829	8,778		8,77
St. Clair	6,516		6,516	8,376		8,37
Randolph	6,484	4,905	6,484	8,340	6,306	8,34
Perry	6,336	6,328	6,336	8,148	8,136	8,14
Franklin	6,048		4,058	7,776		7,77
Jackson No. 5	5,979		5,979	7,683		7,68
Williamson	6,158		6,158	7,917		7,91
Saline	5,957		5,957	7,659		7,65

Estimated coal costs, including depreciation, but excluding selling expense, range from $2.68 to supply either a unit hydrogenation or synthine plant in the Peoria General Area to $5.51 to supply either a unit hydrogenation or synthine plant in the Clay or Wayne General Areas, per ton of merchantable coal produced. The Northern Knox General Area contains sufficient strippable reserves to supply a unit hydrogenation plant for 40 years and a unit synthine plant for 31 years. The Peoria General Area contains sufficient strippable reserves to supply a unit hydrogenation plant for 58 years and a unit synthine plant for 45 years. The Perry General Area contains sufficient strippable reserves to supply a unit hydrogenation plant for 52 years and a unit synthine plant for 40 years. Estimated strippable reserves in the two remaining General Areas where strippable reserves exist indicate sufficient quantities to supply unit plants for periods ranging from 9 to 21 years in duration. It is contemplated that reserves recoverable by strip mining in these latter General Areas will be combined with underground operations until depleted and that the balance of the coal required to operate a unit plant for 40 years will be recovered from the same General Area by underground mining. Estimated coal costs per ton are summarized as follows:

Coal Costs per Ton for the Initial Unit Synthetic Liquid Fuels Plant
(As of March 31, 1950)

General Area Designation	Hydrogenation			Synthine		
	Underground	Strip	Combined	Underground	Strip	Combined
Southeastern Grundy	$5.46		$5.46	$5.46		$5.46
LaSalle-Grundy	5.48		5.48	5.48		5.48
Bureau-Putnam	5.48		5.48	5.48		5.48
Henry No. 6	4.46	$2.91	4.03	4.46	$2.91	4.12
Northern Knox	4.46	2.68	2.70	4.46	2.68	3.09
Marshall	5.48		5.48	5.48		5.48
Peoria	-	2.68	2.68	-	2.68	2.68
Fulton-Knox	4.44		4.44	4.44		4.44
Vermilion	4.44		4.44	4.44		4.44
Logan	3.58		3.58	3.58		3.58
Macon	3.58		3.58	3.58		3.58
Menard	3.58		3.58	3.58		3.58
Sangamon	3.58		3.58	3.58		3.58
Northern Christian	3.24		3.24	3.24		3.24
Southeastern Montgomery	3.24		3.24	3.24		3.24
Macoupin	3.23		3.23	3.23		3.23
Madison	3.81		3.81	3.81		3.81
Bond	3.83		3.83	3.83		3.83
Clinton	4.44		4.44	4.44		4.44
Marion	4.44		4.44	4.44		4.44
Clay	5.51		5.51	5.51		5.51

Coal Costs per Ton for the Initial Unit Synthetic Liquid Fuels Plant
(As of March 31, 1950)
(Concluded)

General Area Designation	Hydrogenation			Synthine		
	Underground	Strip	Combined	Underground	Strip	Combined
Wayne	$5.51		$5.51	$5.51		$5.51
Jefferson	3.81		3.81	3.81		3.81
Washington	3.83		3.83	3.83		3.83
St. Clair	3.39		3.39	3.39		3.39
Randolph	3.39	$2.58	2.97	3.39	$2.58	3.06
Perry	-	2.95	2.95	-	2.95	2.95
Franklin	3.39		3.39	3.39		3.39
Jackson No. 5	4.40		4.40	4.40		4.40
Williamson	3.58		3.58	3.58		3.58
Saline	3.58		3.58	3.58		3.58

The cost per ton for combined underground and strip mining is weighted according to reserves of strip and underground mined coal for 40 years' production during which period all of the strippable coal is assumed to have been mined out and the balance of the supply produced by underground mining. In some Areas, the combined cost for unit synthine plant supply is higher than for hydrogenation plant supply because of the larger percentage of underground coal required to meet the requirements of the synthine plant.

The unit cost of coal supply per barrel of synthetic liquid fuels final products ranges from $1.23 in the Peoria General Area to $2.43 in the Bureau-Putnam and LaSalle-Grundy General Areas, for the hydrogenation process; and from $1.58 in the Peoria General Area to $3.13 in the Bureau-Putnam General Area, for the synthine process. These costs are summarized as follows:

Total Coal Costs for the Initial Unit Synthetic Liquid Fuels Plants
(As of March 31, 1950)

General Area Designation	Btu Per Pound (As received)(A)	Cost for Hydrogenation			Cost for Synthine Process		
		Per Ton	Per Million Btu	Per Barrel	Per Ton	Per Million Btu	Per Barrel
Southeastern Grundy	11,130	$5.46	24.53¢	$2.40	$5.46	24.53¢	$3.09
LaSalle-Grundy	11,070	5.48	24.75	2.43	5.48	24.75	3.12
Bureau-Putnam	11,040	5.48	24.82	2.43	5.48	24.82	3.13
Henry No. 6	10,020	4.03	20.11	1.97	4.12	20.56	2.59
Northern Knox	10,200	2.70	13.24	1.30	3.09	15.15	1.91
Marshall	11,300	5.48	24.25	2.38	5.48	24.25	3.06
Peoria	10,680	2.68	12.55	1.23	2.68	12.55	1.58
Fulton-Knox	10,450	4.44	21.24	2.08	4.44	21.24	2.68
Vermilion	10,910	4.44	20.35	1.99	4.44	20.35	2.56
Logan	10,750	3.58	16.65	1.63	3.58	16.65	2.10
Macon	10,700	3.58	16.73	1.64	3.58	16.73	2.11
Menard	10,730	3.58	16.68	1.63	3.58	16.68	2.10

Total Coal Costs for the Initial Unit Synthetic Liquid Fuels Plants
(As of March 31, 1950)
(Concluded)

General Area Designation	Btu Per Pound (As received)(A)	Cost for Hydrogenation			Cost for Synthine Process		
		Per Ton	Per Million Btu	Per Barrel	Per Ton	Per Million Btu	Per Barrel
Sangamon	10,660	$3.58	16.79¢	$1.65	$3.58	16.79¢	$2.12
Northern Christian	10,870	3.24	14.90	1.46	3.24	14.90	1.88
Southeastern Montgomery	10,760	3.24	15.06	1.48	3.24	15.06	1.90
Macoupin	10,740	3.23	15.04	1.47	3.23	15.04	1.90
Madison	10,750	3.81	17.72	1.74	3.81	17.72	2.23
Bond	10,800	3.83	17.73	1.74	3.83	17.73	2.23
Clinton	10,870	4.44	20.42	2.00	4.44	20.42	2.57
Marion	11,200	4.44	19.82	1.94	4.44	19.82	2.50
Clay	11,370	5.51	24.23	2.37	5.51	24.23	3.05
Wayne	11,440	5.51	24.08	2.36	5.51	24.08	3.03
Jefferson	11,980	3.81	15.90	1.56	3.81	15.90	2.00
Washington	11,000	3.83	17.41	1.71	3.83	17.41	2.19
St. Clair	10,980	3.39	15.44	1.51	3.39	15.44	1.95
Randolph	10,980(B)	2.97	13.52	1.32	3.06	13.92	1.75
Perry	11,305	2.95	13.05	1.28	2.95	13.05	1.64
Franklin	11,830	3.39	14.33	1.40	3.39	14.33	1.81
Jackson No. 5	11,670	4.40	18.85	1.85	4.40	18.85	2.38
Williamson	11,910	3.58	15.03	1.47	3.58	15.03	1.89
Saline	12,310	3.58	14.54	1.42	3.58	14.54	1.83

Note: (A) Weighted average using all available strip coal in first plant with balance of coal required for 40 years' operation being underground.
(B) For hydrogenation 10,980 and for synthine 10,990.

The estimates of costs presented in this survey are based on available information and on generalized, present-day methods of mining and preparation. The installation of mining operations to provide coal supply for a specific synthetic liquid fuels plant should be preceded by detailed engineering studies, including drilling programs, before final methods of operation and firm estimates of costs can be established.

Incremental Cost of Coal for Ultimate Unit Plants. The foregoing estimates represent weighted average costs assuming that strip coal will be used to the fullest extent in General Areas Nos. 4, 5, 7, 26, and 27. For the purpose of cost estimates no strip mining was considered in the other Areas. One unit plant in Areas Nos. 4, 5, and 26 would consume all of such coal within a 40-year period, and in Areas Nos. 7 and 27, within an 80-year period. Therefore a single unit plant in any Area operating beyond 40 or 80 years or more than one or two plants per Area during 40 years would eventually require the use of underground coal exclusively. Under such circumstances, the total costs of coal in those Areas would be:

Total Cost of Coal for Ultimate Synthetic Liquid Fuels Unit Plants
Using Underground Mined Coal Exclusively
(As of March 31, 1950)

General Area Designation	Btu per Pound (As received)	Cost for Hydrogenation Process			Cost for Synthine Process		
		Per Ton	Per Million Btu	Per Barrel of Products	Per Ton	Per Million Btu	Per Barrel of Products
Henry No. 6	10,050	$4.46	22.19¢	$2.17	$4.46	22.19¢	$2.80
Northern Knox (D)	10,200	4.46	21.86	2.14	4.46	21.86	2.75
Peoria	10,700	4.44(A)	20.75	2.03	4.44(C)	20.75	2.61
Randolph	11,030	3.39	15.37	1.51	3.39	15.37	1.94
Perry	11,290	3.39(B)	15.01	1.47	3.39	15.01	1.89

Note: (A) Some strip coal would be available for a second plant in this General Area and its use would result in a cost per ton (for a second plant only) of $3.66
(B) Ditto 3.26
(C) Ditto 4.23
(D) Only 25 years' supply of coal for a hydrogenation unit plant or 11 years' supply for a coal synthine plant is available after the first 40 years' operation of a unit plant.

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WATER SUPPLY PLAN AND ESTIMATES OF COST FOR GENERAL AREAS

Description of Water Supply Projects for General Areas

In order to permit more detailed studies for water supply developments for each General Area, and to prepare cost estimates, a representative plant site, or terminal point for the water works system, has been arbitrarily selected. While proposed receiving points for coal and topographic and geographic features of the area are considered in the selection of such a point, it is, in the final analysis, arbitrary and is in no way intended to represent a recommended plant location.

Similarly, the source of water for the unit plant in each Area is chosen as being representative of development cost for the Area. Most of the projects chosen for making cost estimates have been checked by field surveys, but detailed investigations are beyond the scope of this report. It may be expected, therefore, that in some instances the projects could not be built as described.

Facilities Required. The water supply projects are made up of the facilities required for conserving stream runoff and transporting water from the selected source to the arbitrary plant location and for temporary storage and treatment works at this terminal point. The projects are based upon a water supply system adequate for a single 10,000-barrel-per-day synthetic liquid fuels plant and its supporting population. The principal elements of the water supply system which are discussed in the following paragraphs are assumed to be representative of the requirements for each of the General Areas in Illinois.

Impounding Reservoirs. Impounding reservoirs would be required on the smaller streams to furnish water during dry-weather periods of low flow. The method for determining the size of the reservoir required is discussed earlier in this report. On the larger rivers, no impounding reservoirs would be required, but in many instances a low intake dam might be necessary to provide sufficient water depth. The impounding reservoirs generally would be less than 100 feet in depth and, in most cases, the dams would consist of earth embankments and concrete spillways. Suitable earth-fill materials have been found for the construction of municipal water supply dams in the area, and generally this type would be the most satisfactory and economical.

Wells. Wells are to be the source of domestic water supply for five Areas along the Illinois River. The construction cost estimates are on a basis of 3-mgd production. In the northern portion of the State, the wells would generally be in rock and 1,500 to 2,500 feet in depth with a water-table about 500 feet below the surface. In the central part of the State, drift wells

could be used between 100 and 200 feet in depth, with a water level estimated at 60 feet below the surface.

Pumping Stations. Pumping stations would be required for the water supply systems in all General Areas. The river gradients and terrain are comparatively flat, therefore, the pumping head would be low. Since the river gradients are flat, it would not be economical to extend the intake upstream to a point where gravity flow could be obtained. For a unit synthetic liquid fuels plant requiring 13.1 mgd, or 20.3 cfs, the pumping station would consist of three electrically driven pumps of approximately 8-mgd capacity each, with auxiliary stand-by gasoline engines for two of the pumps. The total pumping head would vary for each of the several General Areas and would depend upon the difference in elevation between the intake and the assumed plant location and the head loss due to friction in the pipe line. In the estimates, an additional allowance of 50 feet has been made for hydraulic losses in the treatment plant and for the distribution of water in the synthetic liquid fuels plant.

Aqueducts. A 30-inch pressure pipe is proposed along the most probable route from the water works intake to the assumed plant location. In a few instances, canals might be used advantageously. However, the feasibility and desirability of canals could not be determined without a detailed investigation in the field and the difference in cost between a canal or pipe line for the transmission of relatively small quantities of water would not be considerable. In the Areas where surface water would not be used for domestic purposes, a 27-inch pipe line is assumed.

Electric Power Transmission Lines and Substations. It is assumed that electric power for operating the pumps would be generated at the synthetic liquid fuels plant and would be transmitted to the pumping station by means of a power transmission line extending along the pipe line right-of-way. The cost of power delivered to the pumping station, estimated in this manner, would be substantially the same as the cost of power available from the several utility companies in Illinois. There are no existing or proposed Federal hydroelectric power projects in Illinois from which low-cost power might be obtained.

Storage Basin at Assumed Plant Site. A 13-million-gallon storage basin, equal to one day's supply, is included to provide a reserve source of water in the event of pump failures or a break in the pipe line and also to serve as a settling basin for the removal of turbidity during periods of high water. It is expected that the settled water from the basin would be of suitable quality for cooling purposes and for coal preparation. An 11-million-gallon reservoir is provided where the domestic water is supplied from wells.

Filter Plant. Filtered water would be required in most instances for the domestic water supply, for the sanitary water in plant and mine, for boiler make-up, and for other minor process uses. It is estimated that 3.5 mgd, or 27 percent of the total supply, would require filtration. A filter plant of 5-mgd capacity is included in order to take care of peak demands, particularly during the summer months when domestic requirements might be unusually high. The cost of filtered water storage is included in the treatment plant estimates. No allowance is made for softening of boiler water since this is considered a process cost. In those Areas where domestic water supplies would be obtained from wells, two filter plants are included, a 3-mgd plant for iron removal, softening, etc., for domestic water supply, and a 2-mgd filter plant for the treatment of process water.

Costs of Water Supply Projects for Suitable General Areas

Total construction costs and annual costs have been estimated on the basis of prices prevailing as of March 1950. Since it is assumed that water supply for a synthetic liquid fuel plant's supporting population would be paid for by the consumers, these costs have been allocated between domestic and process supply on the basis of use. It is to be noted that about 55 percent of the filter plant costs is chargeable to domestic supply, whereas only about 15 percent of the other water supply components is allocated to domestic consumers.

Capital Costs. Construction cost estimates are based on works necessary for a single unit synthetic liquid fuels plant. The indicated cost trends for large water supplies for full development of the fuel resources are approximate since they assume full development at one time. Step-by-step construction over a period of many years is more likely, and the savings in water costs indicated for an immediate full-scale development could not be realized in many instances. All construction cost estimates include an allowance of about 20 percent for engineering and contingencies.

Annual Costs. The principal elements of annual cost have been estimated as follows:

Power. Electric power required for pumping the water from the source to the assumed plant site is based upon a wire-to-water efficiency of 75 percent and a unit cost of 7 mills per kilowatthour. An allowance for transmission and transformer losses is included in the estimated power requirements.

Labor and Superintendence. This has been estimated at $20,000 per year in all areas except those using ground water for domestic supply where it is estimated as $23,000 per year.

Miscellaneous Supplies and Repairs. These have been estimated at $5,000 per year in all areas except those using ground water for domestic supply where it is estimated at $5,800.

Filtration. It is recognized that chemical costs would vary substantially in the several areas. However, a total unit operating cost of $15 per million gallons is assumed to be representative of filter plant costs in the region. This figure includes all operating costs, such as labor, chemicals, supervision, repairs and maintenance.

Fixed Charges. Property taxes and insurance have been taken as one percent of the total depreciable capital costs. Depreciation is estimated on a straight-line basis, with a 40-year life assumed for major structures, such as dams, buildings and pipe lines; and a 20-year life for equipment, such as motors, pumps and transformers. Return on the investment or interest is not included in the fixed charges for water supply, so the estimates show the cost of water without this item. There is shown, however, the additional cost to water supply which would be incurred if interest at one percent were included.

Costs of Water by Suitable General Areas

The paragraphs following include a brief description of water supply developments for each General Area, with a summary statement of the estimated construction costs and annual costs allocated between domestic and process water supply. A unit water cost per barrel of product is shown which includes only that water properly chargeable to process and mining. The cost trends for complete development of all the fuel resources are also indicated. A more detailed summary of the water supply costs for each General Area is shown on Exhibit No. 26 and a map of the water supply plan for each General Area is shown on Exhibit No. 27.

Southeastern Grundy - General Area No. 1. Cost estimates for this Area are based upon an intake and pumping station for process water on the Illinois River, a 6-mile pipe line to the assumed plant site, a storage basin, and treatment works. A separate, deep rock well supply and treatment works for domestic supply are included. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26 are:

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Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$1,301,000	$105,310
Domestic	605,000	57,050
Total	$1,906,000	$162,360

Cost of water for process use - $0.029 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.004.

Full development of the coal resources in the Area with a daily production of 13,000 barrels of synthetic liquid fuels would require 22 cfs of process water and 4 cfs for domestic needs. The process water could be obtained from the Illinois River at about 10 percent smaller unit cost than for the 10,000-barrel plant.

La Salle-Grundy - General Area No. 2. Cost estimates for this Area are based upon an intake and pumping station for process water on the Illinois River below the Marseilles Dam, a 1-mile pipe line to the assumed plant site, a storage basin, and treatment works. A separate, deep rock well supply and treatment works for domestic supply are included. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$ 632,000	$75,020
Domestic	605,000	57,050
Total	$1,237,000	$132,070

Cost of water for process use - $0.021 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.002.

Full development of the coal resources in the Area with a daily production of 21,000 barrels of synthetic liquid fuels would require 36 cfs of process water and 7 cfs for domestic needs. The process water could be obtained from the Illinois River at about 25 percent smaller unit cost than for the one 10,000-barrel plant.

Bureau-Putnam - General Area No. 3. Cost estimates for this Area are based upon an intake and pumping station for process water on the Illinois River, a 1-mile pipe line to the assumed plant site, a storage basin, and treatment works. A separate, deep rock well supply and treatment works for domestic supply are included. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$687,000	$83,570
Domestic	605,000	57,050
Total	$1,292,000	$140,620

Cost of water for process use - $0.023 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.002.

Full development of the coal resources in the Area for the daily production of 26,000 barrels of synthetic liquid fuels would require 45 cfs of process water and 7 cfs for domestic needs. The process water could be obtained from the Illinois River at about 25 percent smaller unit cost than for one 10,000-barrel plant.

Complete Development of the Coal Resources of General Areas Nos. 1, 2, and 3. If the coal resources of the three Areas were fully developed for the daily production of 60,000 barrels of synthetic liquid fuels 103 cfs of process water would be required. Withdrawal of this quantity of water from the Illinois River would reduce the minimum daily flow at Marseilles by about 7 percent, and at Peoria by about 4 percent. If there should be local objection to reducing the amount of water available for diluting wastes at Peoria, the low flow could be supplemented from a storage reservoir on Covel Creek (Reservoir No. 32, Exhibit Nos. 19 and 27), in LaSalle County. The carrying charges on this reservoir when prorated against the total production of synthetic liquid fuels plants in the three Areas would amount to about $0.006 per barrel of fuel with about $0.0018 per barrel added for each 1 percent gross return on investment.

Henry No. 6 - General Area No. 4. Cost estimates for this Area are based upon a 15,000-AF storage reservoir on Spoon Creek (Reservoir No. 26, Exhibits Nos. 19 and 27), a pumping station, a 12-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a 10,000 barrel-per-day synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,664,000	$238,100
Domestic	1,026,000	60,800
Total	$5,690,000	$298,900

Cost of water for process use - $0.065 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.013.

Full development of the coal resources in the Area for synthetic liquid fuels would support a daily production of 24,000 barrels of fuel and would require 49 cfs of water. The reservoir on Spoon Creek could be increased in capacity to furnish this quantity of water. The unit cost of water for a development of this size then would be about 25 percent less than for the 10,000-barrel-per-day plant.

Northern Knox - General Area No. 5. Cost estimates for this Area are based upon a water supply from a 21,000-AF storage reservoir on Walnut Creek, (Reservoir No. 25, Exhibit No. 19 and 27), a pumping station, a 3-1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a 10,000-barrel synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,068,000	$208,540
Domestic	922,000	55,660
Total	$4,990,000	$264,200

Cost of water for process use $0.057 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.011.

Full development of the coal resources in the Area for synthetic liquid fuels would support a daily production of 13,000 barrels of fuel and would require 26 cfs of water. The reservoir on Walnut Creek could be increased in capacity to furnish this quantity of water. The unit cost of water then might be about 10 percent less than that for a single 10,000-barrel plant.

Marshall - General Area No. 6. Coal resources in this Area are sufficient for the production of only 8,000 barrels of synthetic liquid fuels daily by the coal synthine process, and 10,000 barrels by the coal hydrogenation process. Nevertheless, cost estimates for this Area are based upon a 20-cfs water-supply system. The estimates include an intake and pumping station for process water on the Illinois River, an 11-mile pipe line to the assumed plant site, a storage basin, and treatment works. A separate, deep rock well supply and treatment works for domestic use are included. The estimated costs, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,090,000	$163,500
Domestic	605,000	57,050
Total	$2,695,000	$220,550

Cost of water for process use - $0.045 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.006.

Peoria - General Area No. 7. Cost estimates for this Area are based upon an intake and pumping station for process water on the Illinois River, a 2-1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. A separate, drift well supply and treatment works for domestic purposes are included. The estimated costs for a single unit synthetic liquid fuels plant, as shown in Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$ 971,000	$ 109,210
Domestic	430,000	38,200
Total	$1,401,000	$ 147,410

Cost of water for process use - $0.030 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.003.

Full development of the coal resources in this Area with a daily production of 51,000 barrels of synthetic liquid fuels would require 88 cfs of process water and 15 cfs for domestic needs. The process water could be obtained from the same source at about 25

percent less unit cost than for a 10,000-barrel plant. The removal of 88 cfs from the Illinois River at this point would reduce the water available for dilution of wastes below Peoria and might give rise to local objection. This would be most likely if other Areas taking water from the Illinois River above Peoria were developed simultaneously. The low flows of the Illinois River could be augmented for synthetic liquid fuels requirements from storage available for water-supply purposes in the proposed Jubilee flood control reservoir on Kickapoo Creek (Reservoir A, Exhibits Nos. 20 and 27) in the event the Corps of Engineers should find its construction feasible. The prorated cost of the 21,000 AF of storage required for low flow regulation would amount to about $0.0025 per barrel of fuel with about $0.0018 per barrel added for each 1 percent gross return on investment. In the event of a large scale synthetic liquid fuels development within the Area, it is unlikely that enough water for domestic purposes could be obtained from wells. In this case, the domestic water requirements could probably be obtained directly from the Jubilee Reservoir. If, as stated before, the Jubilee Reservoir should not be built, or if its storage should be allocated for other purposes, storage reservoirs at somewhat higher unit costs on tributaries further upstream on the Illinois River might be developed to supplement low flow.

Fulton-Knox - General Area No. 8. Cost estimates for this Area are based upon a water supply utilizing 27,000 AF of storage in the proposed London Mills Reservoir, on the Spoon River (Reservoir B, Exhibits Nos. 20 and 27), now under consideration by the Corps of Engineers for flood control. The estimates include, in addition, a pumping station, a 7-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a 10,000-barrel per day synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,581,000	$229,970
Domestic	1,011,000	59,350
Total	$5,592,000	$289,320

Cost of water for process use - $0.063 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.013.

For comparative purposes, the cost of storage is based on construction of a small reservoir, adequate for synthetic liquid fuels water supply alone. If the London Mills Reservoir were constructed to provide flood control and a water supply for a synthetic liquid fuels plant, the cost of storage chargeable to such a plant would be substantially less, resulting in a water-works cost of about 50 percent of that indicated in the preceding table. Water

might be economically obtained from the Illinois River if storage was not available for synthetic liquid fuels in the London Mills Reservoir.

Full development of the coal resources in the Area with a daily production of 29,000 barrels of synthetic liquid fuels would require 59 cfs. This quantity of water could be obtained by utilizing 42,000-AF of the 62,000-AF available for water supply and navigation in the proposed London Mills Reservoir. The unit cost would be about 50 percent of the cost of water for the single unit synthetic liquid fuels plant.

If the London Mills Reservoir should not be built or if its storage should be allocated for other purposes, water could be obtained from the Illinois River, 21 miles distant at slightly higher costs for construction and per barrel of products.

Vermilion - General Area No. 9. Cost estimates for this Area are based on a water supply from a 25,000-AF storage reservoir on the Middle Fork of the Vermilion River (Reservoir No. 39, Exhibit Nos.19 and 27), a pumping station, a 9-1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,945,000	$236,010
Domestic	1,075,000	60,390
Total	$6,020,000	$296,400

Cost of water for process use - $0.065 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.014.

Full development of the coal resources in the Area with a daily production of 43,000 barrels of synthetic liquid fuels would require 87 cfs. The reservoir on the Middle Fork of the Vermilion River could be increased in capacity to furnish this amount. The estimated unit cost for water of a development of this size would be approximately 50 percent of the unit cost of water for a single 10,000-barrel plant because of the use of larger pipe and larger plant units.

Logan - General Area No. 10. Cost estimates for this Area are based on a water supply from Salt Creek, utilizing 20,000-AF of storage in the proposed Kenney flood control reservoir, 17 miles east of the assumed plant site, in DeWitt County. Water for synthetic liquid fuels plant use could be let down from the Kenney

Reservoir (Reservoir G, Exhibit Nos. 20 and 27) and withdrawn from Salt Creek at an intake 1/2 mile from the assumed plant site. The cost estimates include the pumping station, the 1/2 mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,783,000	$173,790
Domestic	872,000	49,660
Total	$4,655,000	$223,450

Cost of water for process use - $0.048 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.010.

For comparative purposes, the cost of storage is based on construction of a small reservoir adequate for synthetic liquid fuels water supply alone. If the Kenney reservoir were constructed to provide flood control and a water supply for a synthetic liquid fuels plant, the cost of storage chargeable to such a plant would be substantially less resulting in a water-works cost of about 50 percent of that indicated in the preceding table.

Full development of the coal resources in the Area for synthetic liquid fuels would support a daily production of 21,000 barrels and would require 43 cfs. This quantity of water could be obtained by utilizing 31,000 AF of the 34,000 AF available for water supply and navigation in the proposed Kenney Reservoir. The unit cost would be about 75 percent of the cost of water for the single unit synthetic liquid fuels plant water supply. If storage should not be available from the proposed Kenney Reservoir, water would have to be obtained from the Illinois River or other distant source at a much higher unit cost.

Macon - General Area No. 11. Cost estimates for this Area are based on a water supply from a 24,000-AF storage reservoir on West Okaw River, (Reservoir No. 12, Exhibits Nos. 19 and 27), a pumping station, a 28-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown in Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$6,955,000	$321,710
Domestic	1,425,000	75,190
Total	$8,380,000	$396,900

Cost of water for process use - $0.088 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.019.

Full development of the coal resources in the Area with a daily production of 21,000 barrels of synthetic liquid fuels would require 43 cfs. This supply could be obtained most economically by building a pipe line direct to the Illinois River which would yield a unit cost approximately 25 percent less than that indicated for the supply from the West Okaw River for a single 10,000-barrel-per-day plant.

Surplus water would not be available from the proposed Oakley flood control reservoir and there is no excess in Lake Decatur. The city of Decatur has requested that when Oakley Reservoir is built, a pool for water supply be included. The proposed Kenney flood control reservoir north of the Area might be used for a small development unless all of the storage capacity was required in connection with the development in Area No. 10.

Menard - General Area No. 12. Cost estimates for this Area are based upon a 23,100-AF reservoir on Richland Creek (Reservoir No. 22, Exhibit Nos. 19 and 27), from which process water would be let down to an intake located near the assumed plant site on the Sangamon River, a pumping station, a 1/2-mile pipe line, a storage basin, and treatment works. Water for domestic purposes would be piped directly from the Richland Creek Reservoir to its point of use. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,671,000	$201,370
Domestic	854,000	54,380
Total	$4,525,000	$255,750

Cost of water for process use - $0.055 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.010.

Full development of the coal resources in the Area with a daily production of 35,000 barrels of synthetic liquid fuels would require 60 cfs of process water and 11 cfs for domestic needs. The process water required in excess of that for a single unit plant could be obtained from the Illinois River at about the same unit cost because of the use of larger pipe and larger plant units. Reservoirs for supplementing low flows in this section of the Illinois River are not required because there is no considerable pollution downstream and because the navigation requirements would not be affected by the withdrawal of the necessary quantities of water. The total domestic water requirement for a full development of the coal resources in this area could be obtained from the Richland Creek Reservoir.

Sangamon - General Area No. 13. Cost estimates for this Area are based upon a water supply from an 18,500-AF storage reservoir on Lick Creek (Reservoir No. 23, Exhibit Nos. 19 and 27), a pumping station, a 3-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,961,000	$ 184,270
Domestic	903,000	51,470
Total	$4,864,000	$ 235,740

Cost of water for process use - $0.050 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.011.

If the full coal resources of the Area were developed to produce 187,000 barrels of synthetic liquid fuels daily, 379 cfs of water would be required. Some of this water could be obtained by raising the reservoir on Lick Creek. The full requirements could be met, in any event, by the construction of a pipe line 40 to 50 miles long to the Illinois River. It is estimated that the unit cost for such a development would be about 25 percent less than the cost for building the smaller supply on Lick Creek.

If the Illinois River was used for a very large development in Sangamon County, other sources would have to be developed for domestic requirements. Lake Springfield (Reservoir Q, Exhibit No. 27), which is the source of water supply for the city of Springfield, has some capacity in excess of present needs, and it is estimated that 15 to 20 cfs could be obtained for domestic supplies

from the lake. The additional water for domestic purposes could be obtained from the Rochester Dam if it is constructed, or from the Lick Creek Reservoir.

Northern Christian - General Area No. 14. Cost estimates for this Area are based upon a water supply from a 21,000-AF storage reservoir on the South Fork of Sangamon River (Reservoir No. 24, Exhibits Nos. 19 and 27), a pumping station, a 5-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,165,000	$197,610
Domestic	939,000	53,730
Total	$5,104,000	$251,340

Cost of water for process use - $0.054 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.011.

If the coal resources of the Area were fully developed, 106,000 barrels of synthetic liquid fuels could be produced daily, and 215 cfs of water would be required. The reservoir on the South Fork of the Sangamon River could be increased in capacity to yield 45 cfs, and the remaining 170 cfs might be obtained from the proposed Shelbyville flood control reservoir (Reservoir N, Exhibits Nos. 20 and 27), on the Kaskaskia River, 28 miles distant. As presently planned by the Corps of Engineers, the Shelbyville Reservoir will have 180,000 AF of storage capacity in excess of flood control requirements and the usual conservation pool. A total of 160,000 AF would have to be allocated to synthetic liquid fuels in order to assure a supply of 170 cfs. On the assumption that this type of development would be possible, the unit cost of water for the full development of the resources would be about 25 percent less than the unit cost for a single 10,000-barrel-per-day plant.

Southeastern Montgomery - General Area No. 15. Cost estimates for this Area are based upon a water supply from a 23,000-AF storage reservoir on Ramsey Creek, (Reservoir No. 9, Exhibits Nos. 19 and 27), a pumping station, a 13-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$5,226,000	$251,520
Domestic	1,124,000	63,080
Total	$6,350,000	$314,600

Cost of water for process use - $0.069 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.014.

Full development of the coal resources of the Area to yield 143,000 barrels of synthetic liquid fuels daily would require 289 cfs of water. The capacity of the Ramsey Creek Reservoir could be increased slightly to yield 23 cfs. An additional 80 cfs could be obtained by the construction of reservoirs on the Middle Fork of Shoal Creek, on Becks Creek and on Big Creek (Reservoir Nos. 5, 11, and 10, Exhibits Nos. 19 and 27). The remaining 186 cfs would have to be obtained from the Mississippi River at a point just above the mouth of the Missouri River. The unit cost of water on such a large-scale development would be approximately 25 percent less than the unit cost indicated for a single 10,000-barrel-per-day plant.

If the coal resources in this Area and other adjacent areas taking water from the Mississippi River were developed concurrently for synthetic liquid fuel purposes, the total draft of Mississippi River water might be so great as to require regulation during drought periods. It is estimated that storage capacity of 86,000-AF would be required to provide the 186 cfs needed in this Area to avoid affecting the low flows of the Mississippi River. There are numerous sites available for the construction of reservoirs. It is estimated that the carrying costs on two such reservoirs on Piasa and Otter Creeks, (Reservoir Nos. 14 and 15, Exhibit Nos. 19 and 11), which together would provide the necessary storage, would be approximately $0.010 per barrel of fuel with about $0.003 per barrel added for each 1 percent gross return on the investment.

Macoupin - General Area No. 16. Cost estimates for this Area are based upon a water supply from a 22,000-AF storage reservoir on West Fork of Shoal Creek (Reservoir No. 6, Exhibit Nos. 19 and 27), a pumping station, a 6-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown in Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,245,000	$207,210
Domestic	953,000	55,470
Total	$5,198,000	$262,680

Cost of water for process use - $0.057 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.012.

If the coal resources of the Area were fully developed to yield 218,000 barrels of synthetic liquid fuels daily, 441 cfs would be required. A total yield of 178 cfs could be obtained from the reservoir on the West Fork of Shoal Creek and from reservoirs on Otter and Macoupin Creeks (Reservoirs Nos. 16 and 17, Exhibit Nos. 19 and 27). The Macoupin Creek site had been considered by the Corps of Engineers for flood control purposes. The additional 263 cfs required would have to be obtained from the Mississippi River, approximately 41 miles from the assumed plant site. If all of the water required were obtained initially from the Mississippi River, the unit cost would be less than 50 percent of the cost for the single 10,000-barrel-per-day plant.

The withdrawal of 263 cfs from the Mississippi River near Alton would require the construction of storage reservoirs for providing water for synthetic liquid fuel purposes during drought periods when the entire flow of the Mississippi River was required for navigation. There are numerous reservoir sites which might be developed for such low-flow augmentation for this Area, among which is a site on McKee Creek (Reservoir No. 19, Exhibit Nos. 19 and 11) in Brown County. If the carrying charges on such a reservoir were assessed against the synthetic liquid fuels production that could be supported by it, the unit cost for river regulation would be $0.006 per barrel of fuel with about $0.0018 per barrel added for each 1 percent return on the investment.

Madison - General Area No. 17. The cost estimates for this Area are based on an intake and pumping station on the Mississippi River just above the mouth of the Missouri, a 13-1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,064,000	$146,000
Domestic	574,000	44,780
Total	$2,638,000	$190,780

Cost of water for process use - $0.040 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.006.

Full development of the coal resources of the Area with a daily production of 53,000 barrels would require 107 cfs. This quantity of water could be obtained from the Mississippi River at about 50 percent smaller unit costs because of the use of larger pipe and larger plant units.

In the event of a large-scale synthetic liquid fuels development along this section of the Mississippi River, several reservoir sites such as the one on Indian Creek in Morgan County (Reservoir No. 20, Exhibit Nos. 19 and 11), are available to provide river regulation during periods of low flow. It is estimated that the cost of such river regulation assessed against the cost of synthetic liquid fuels in this Area would amount to $0.010 per barrel of fuel with about $0.0018 per barrel added for each 1 percent return on the investment.

Bond - General Area No. 18. Cost estimates for this Area are based on a water supply from a 23,000-AF storage reservoir on the East Fork of Shoal Creek (Reservoir No. 4, Exhibits Nos. 19 and 27), a pumping station, a 2-1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,019,000	$193,550
Domestic	913,000	52,970
Total	$4,932,000	$246,520

Cost of water for process use - $0.053 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.011.

Full development of the coal resources in the Area with a daily production of 24,000 barrels of synthetic liquid fuels would require 49 cfs. This quantity of water could be obtained by increasing the capacity of the reservoir on the East Fork of Shoal Creek to about 58,000 AF. The unit cost of this development then would be about 25 percent less than the unit cost of water for a single 10,000 barrel per day plant.

Clinton - General Area No. 19. Cost estimates for this Area are based on a water supply utilizing 23,000 AF of storage in a reservoir on the East Fork of Kaskaskia River (Reservoir No. 8, Exhibits Nos. 11 and 19). The water would be let down the river to an intake near the assumed plant site. The estimates also include a pumping station, a 1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,595,000	$165,010
Domestic	840,000	48,140
Total	$4,435,000	$213,150

Cost of water for process use - $0.045 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.010.

For comparative purposes, the cost of storage is based on construction of a small reservoir adequate for synthetic liquid fuels water supply alone. If the Carlyle Reservoir were constructed to provide flood control and water supply for a synthetic liquid fuels plant, the cost of storage would be substantially reduced resulting in a water-works cost of less than 40 percent of that indicated in the preceding table.

Full development of the coal resources in the Area with a daily production of 86,000 barrels of synthetic liquid fuels would require 174 cfs. This quantity of water could be obtained by utilizing 183,000 AF of the 300,000 AF of storage available in the proposed reservoir in excess of flood control and conservation requirements. The unit water costs for full development of the coal resources would be about half of that for the single 10,000-barrel-per-day plant.

If the Carlyle Reservoir was not built, or if water was not available from it for the production of synthetic liquid fuels sufficient water could be obtained from the Mississippi River, but at considerably higher unit cost.

Marion - General Area No. 20. Cost estimates for this Area are based upon a water supply from a 24,000-AF storage reservoir on Crooked Creek (Reservoir No. 7, Exhibits Nos. 19 and 27), a pumping station, a 1-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,829,000	$179,150
Domestic	881,000	50,550
Total	$4,710,000	$229,700

Cost of water for process use - $0.049 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.010.

Full development of the coal resources in the Area with a daily production of 17,000 barrels of synthetic liquid fuels daily would require 34 cfs. The capacity of the reservoir on Crooked Creek could be increased to yield 26 cfs, or a second reservoir might be built on the East Fork of the Kaskaskia River (Reservoir No. 8, Exhibit Nos. 19 and 27), which would yield approximately 28 cfs. The unit cost of water for the complete development of the coal resources would be somewhat greater than for a single 10,000-barrel-per-day plant because of the necessity of building two reservoirs.

Clay - General Area No. 21. Cost estimates for this General Area must be very approximate because only a small part of Clay and Effingham Counties have been mapped by the U.S. Geological Survey. There are no suitable reservoir sites in the mapped portions of the counties, but it seems likely that reservoir sites do exist in the upper tributaries of the Little Wabash River in Effingham County because the terrain is more rugged than in the lower Little Wabash River basin. The cost estimates for this Area, therefore, are based on a water supply from an assumed regulatory reservoir upon an upper tributary of the Little Wabash River. The water would be let down the river to an intake near the assumed plant site. The estimates include in addition, a pumping station, a 1-mile pipe line, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,616,000	$169,920
Domestic	844,000	48,780
Total	$4,460,000	$218,700

Cost of water for process use - $0.047 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.010.

If reservoirs could not be built in or near the Area, sites available on the tributaries of the Embarrass River in Cumberland and Jasper Counties, 35 miles distant from the assumed plant site could be developed or water might be taken from the Wabash River, 50 miles away. Both of these proposals would result in a unit cost substantially higher than that indicated in the preceding table:

Wayne - General Area No. 22. Cost estimates for this Area are based upon an intake and pumping station on the Wabash River, an 18-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,603,000	$175,190
Domestic	667,000	49,710
Total	$3,270,000	$224,900

Cost of water for process use - $0.048 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.007.

Full development of the coal resources in the area with a daily production of 36,000 barrels of synthetic liquid fuel would require 73 cfs. This larger quantity of water could be obtained from the same source at about 25 percent smaller unit cost because of the use of larger pipe and larger plant units.

Jefferson - General Area No. 23. Cost estimates for this Area are based upon a water supply from a 24,000-AF storage reservoir on the Little Muddy River (Reservoir No. 2, Exhibit Nos. 19 and 27), a pumping station, an 11-mile pipe line to the assumed plant site,

a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,984,000	$228,900
Domestic	1,081,000	59,150
Total	$6,065,000	$288,050

Cost of water for process use - $0.063 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.014.

If the coal resources of the Area were fully developed, 68,000 barrels of synthetic liquid fuel could be produced daily, and 138 cfs of water would be required. The capacity of the reservoir on the Little Muddy River could be increased to yield 30 cfs, but the remaining 108 cfs would have to be obtained from the Mississippi River at a distance of 48 miles from the assumed plant site. The unit construction cost for the full development would be about 25 percent less than that for a single 10,000-barrel plant, but the savings in operating and per barrel of fuel costs would be considerably smaller.

Washington - General Area No. 24. Cost estimates for this Area are based upon a water supply from a 25,000-AF storage reservoir on Elkhorn Creek (Reservoir No. 3, Exhibits Nos. 19 and 27), a pumping station, a 1/2-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,897,000	$181,530
Domestic	893,000	50,970
Total	$4,790,000	$232,500

Cost of water for process use - $0.050 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.011.

Full development of the coal resources in the Area with a daily production of 24,000 barrels of synthetic liquid fuels would require 49 cfs. Practically all of the additional water would have to be obtained from the Mississippi River, 36 miles distant. The unit cost for the full development would be about the same as the cost for a 10,000 barrel per day plant.

St. Clair - General Area No. 25. Cost estimates for this Area are based upon an intake and pumping station on the Mississippi River, a 20-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,796,000	$176,620
Domestic	701,000	50,150
Total	$3,497,000	$226,770

Cost of water for process use - $0.048 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.008.

If the coal resources of the area were fully developed, 110,000 barrels of synthetic liquid fuels could be produced daily, and 223 cfs would be required. This quantity of water could be obtained from the Mississippi River at about one-half the unit costs because of the larger pipe and larger plant units.

Randolph - General Area No. 26. Cost estimates for this Area are based on an intake and pumping station on the Mississippi River, a 19-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,705,000	$178,510
Domestic	685,000	50,390
Total	$3,390,000	$228,900

Cost of water for process use - $0.049 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.007.

Full development of the coal resources of the Area with a daily production of 39,000 barrels of synthetic liquid fuels would require 79 cfs. This quantity of water could be obtained from the Mississippi River at about 25 percent smaller unit costs.

Perry - General Area No. 27. Cost estimates for this Area are based on an intake and pumping station on the Mississippi River, a 22-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,037,000	$192,030
Domestic	743,000	52,770
Total	$3,780,000	$244,800

Cost of water for process use - $0.053 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.008.

If the coal resources of the Area were fully developed, 125,000 barrels of synthetic liquid fuels could be produced daily, and 253 cfs would be required. This quantity of water could be obtained from the Mississippi River at somewhat less than half the unit cost for a 10,000-barrel-per-day plant, because of the use of larger pipe and larger plant units.

Franklin - General Area No. 28. Cost estimates for this Area are based upon an intake and pumping station on Big Muddy River, an 11-mile pipe line to a 19,300-AF storage reservoir on Sugarcamp Creek, a pumping station at the dam and 2-1/2 miles of pipe to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$5,101,000	$239,070
Domestic	1,102,000	60,960
Total	$6,203,000	$300,030

Cost of water for process use - $0.065 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.014.

If the coal resources of the Area were fully developed, 87,000 barrels of synthetic liquid fuels could be produced daily and 176 cfs could be required. This quantity of water could be obtained from the Mississippi River at about 50 percent of the cost for water for a 10,000-barrel-per-day plant.

Jackson - No. 5 General Area No. 29. Cost estimates for this Area are based upon an intake and pumping station on the Mississippi River, a 22-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26 are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,024,000	$189,700
Domestic	741,000	52,350
Total	$3,765,000	$242,050

Cost of water for process use - $0.052 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.008.

Full development of the coal resources with a daily production of 39,000 barrels of synthetic liquid fuels would require 79 cfs. This quantity of water could be obtained from the Mississippi River at about 25 percent lower unit cost than for a water supply for a 10,000-barrel-per-day plant.

Williamson - General Area No. 30. Cost estimates for this Area are based upon an intake and pumping station on the Ohio River, a 34-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26 are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,506,000	$275,120
Domestic	999,000	67,230
Total	$5,505,000	$342,350

Cost of water for process use - $0.075 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.012

Full development of the coal resources in the Area with a daily synthetic liquid fuels production of 55,000 barrels would require 111 cfs. This quantity of water could be obtained from the Ohio River at about 50 percent lower unit cost than the unit cost for water for a 10,000-barrel plant because of the use of larger pipe and larger plant units.

Saline - General Area No. 31. The estimated costs for this Area are based upon an intake and pumping station on the Ohio River, a 18-mile pipe line to the assumed plant site, a storage basin, and treatment works. The estimated costs for a single unit synthetic liquid fuels plant, as shown on Exhibit No. 26, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,556,000	$163,220
Domestic	659,000	47,630
Total	$3,215,000	$210,850

Cost of water for process use - $0.045 per barrel of products. Increase cost per barrel for each 1 percent gross return on investment - $0.007.

Full development of the coal resources in the Area with a daily production of 107,000 barrels of synthetic liquid fuels would require 217 cfs. This quantity of water could be obtained from the Ohio River at about 50 percent lower unit costs than water for a single 10,000 barrel plant because of the use of larger pipe and larger plant units.

POWER

Requirements

For a 10,000-barrel-per-day plant using the coal synthine process, it is estimated that the power requirements will amount to 114,500 kw plus 3,500 kw for the mine. However, as waste heat recovery arrangements will have sufficient output to supply the steam needed to generate this amount of electricity, it would not be economical to bring in power from any outside source such as a hydroelectric development or a utility.

For a 10,000-barrel-per-day plant using the hydrogenation process, it is estimated that the total power load will be 65,000 kw at 100 percent load factor. Only 40,000 kw of this can be classed as prime power because the remaining 25,000 kw will be by-product power produced in conjunction with process steam. The 40,000 kw of prime power plus 3,000 kw of mine load would be supplied from the most economical source of power, whether it be a generating station constructed as an integral part of the synthetic liquid fuels plant, a hydroelectric development, or a public utility.

Existing Facilities

On page 2 of Exhibit No. 28, a map, there are indicated the power facilities now available in the coal-producing area of Illinois, and on page 1 of that exhibit are listed the data as to their identification, ownership, and capacity.

Seventeen of the 31 General Areas for the location of synthetic liquid fuels plants are served by the Illinois Power Company, nine by the Central Illinois Public Service Company, two by the Public Service Company of Northern Illinois, two by the Central Illinois Light Company, and one by the Union Electric Power Company.

The Illinois Power Company serves a large part of the coal-producing area of Illinois. This Company has a well-balanced system, centered chiefly at its two largest stations, Havana and Wood River, has a present generating capacity (1950) of 235,164 kw, with units under construction to add 180,000 kw more capacity by the end of 1950 and a further 120,000 kw additional by 1953. This company also has interconnections with both the Union Electric Company system of St. Louis and the Commonwealth Edison Company system in Chicago.

The Central Illinois Electric and Gas Company, which has a plant near Lincoln, Ill., has too small a capacity to be considered among the possibilities for obtaining power for a synthetic liquid fuels plant. The only such possibility would be to arrange with adjacent large producers of power for a supply through the transmission lines of the Central Illinois Electric and Gas Company, from such outside sources.

The Commonwealth Edison Company and its subsidiary, the Public Service Company of Northern Illinois, comprise one of the largest power pools in the United States, with a present (1950) total capacity exceeding 2,000,000 kw, and an estimated additional capacity of 410,000 kw in the course of construction, to be completed by 1953.

The Central Illinois Public Service Company serves a large portion of the coal-producing area, chiefly that portion not served by the Illinois Power Company. This company has presently in excess of 220,000 kw capacity, with additional 120,000 kw capacity to be completed by 1951. This company also has interchange connections with both the Illinois Power Company and the Commonwealth Edison Company systems.

The Central Illinois Light Company operates outside of the Springfield area and also in and around Peoria, with a total present (1950) capacity of 184,400 kw, and an additional capacity of some 60,000 kw to be completed by 1953. This company has interconnections with the three largest power companies in the State, and also has a reserve of capacity estimated in excess of 40,000 kw (in 1949).

The Union Electric Power Company Monsanto, Illinois (controlled by Union Electric Company of St. Louis, Mo.), operates in and around Alton and East St. Louis, Illinois, and Keokuk, Iowa. Its own interconnected system, including 116,000 kw hydroelectric at Keokuk, Iowa, comprises 703,000 kw.

Proposed Hydroelectric Developments

The Corps of Engineers prepared a report entitled "Potential Water Power Sites - As Summarized from Reports by the Corps of Engineers to the Congress - Edition of March, 1935". In this report there were indicated, as potential hydroelectric sites within the State of Illinois, 24 projects which are tabulated below:

Potential Water Power Sites in Illinois
(As of March 1935)

Project No.	Name of Project	Head (Ft)	Capacity (Megawatts)	Cost per Installed Kw	Total Annual Output (Million Kwhr)	Cost per Kwhr (Mills)
917	Lyndon, Rock River	10	4.1	$268	8.0	16.6
918	Above Lyndon, Rock River	9	3.7	295	6.9	19.3
919	Como Rock River	9	3.7	293	6.9	19.2
926	Barstow, Rock River	23	12.5	54	22.3	1.2
1477	Golconda Reservoir, Ohio River	39.5	175.0	165	767.0	2.9
1635	Fox River: No. 1	10	1.7	229	2.1	9.0
1636	No. 3	22	2.9	203	3.6	9.0
1637	No. 4	14	1.7	224	2.1	9.0
1638	No. 5	14	1.7	242	2.0	9.0
1639	No. 6	14	1.7	245	1.9	9.0
1640	No. 7	14	1.5	217	1.7	9.0
1641	No. 8	14	1.5	223	1.6	9.0
1642	No. 9	14	1.5	230	1.6	9.0
1643	No.10	9	0.4	605	1.2	10.0
1644	No.11	9	0.4	519	1.1	8.8
1645	No.12	9	0.4	545	1.1	9.3
1656	Illinois River, Brandon Road	34	21.8	60	33.0	4.9
1657	Starved Rock, Illinois River	13	11.3	165	33.0	4.9
1658	Marseilles, Illinois River	23	8.2	125	18.0	5.5
1659	Dresden Island, Illinois River	19	14.9	97	33.0	4.4
1660	Kankakee River: No. 1A	18	6.6	168	8.0	8.7
1661	No. 2A	11	4.3	221	5.2	10.8
1662	No. 3A	46	15.1	145	18.6	7.5
1663	No. 5A	13	2.9	192	3.5	10.2

It is apparent from the above table that no project listed, except Project No. 1477 - Golconda Reservoir, is large enough to supply even one 10,000-barrel unit synthetic liquid fuels plant. This project is within 60 miles of five General Areas, and within 30 miles of two of those five. The proposed capacity would be large enough to furnish cheap hydro power for two hydrogenation plants.

However, The Corps of Engineers advises that because of economic and other considerations, the Golconda Reservoir plan has been dropped for the present. It is doubtful if all the potential sites not now in operation were combined, that enough firm power

could be made available to supply one synthetic liquid fuels plant, and even then the cost would be higher than the cost of obtaining power from the existing utility plants.

Power Costs

It is estimated that the average cost of producing primary power by steam for a synthetic liquid fuels plant would be about 6 mills per kilowatthour. This estimate includes an allowance for depreciation on a 15-year life basis, but excludes any allowance for return on the investment or for income taxes. The application of a rational depreciation allowance, even with allowances for return and profit, should not materially increase the estimated cost of power. On the other hand, use of the higher ash fractions from coal washing might effect substantial savings in power costs, as compared with the cost of coals suitable for processing to synthetic liquid fuels. Based on their existing rate schedules, the large utilities in Illinois could furnish power to the synthetic liquid fuels plant at the following rates (all subject to fuel adjustment):

	Mills per Kwhr
Public Service Company of Northern Illinois (Rate 12)	6.8
Illinois Power Company	8.8
Central Illinois Light Company (Schedule 11-P-6)	7.7
Central Illinois Public Service Company (Schedule 9)	10.0
Union Electric Power Company (in East St. Louis Area only)	5.1

The cost of purchased power might be materially reduced if contracts were made with two or more of the five larger utilities in the State, whereby the utilities would jointly supply the requirements for power. Illinois utilities are unusually well aligned to jointly supply such a load. No estimate can be made at present of the cost of such power, but, in view of the expected high power and load factors, it is felt that the utilities would be willing to work out an advantageous contract.

The General Areas served by the Public Service Company of Northern Illinois are Southeastern Grundy and Marshall. The Illinois Power Company serves the following General Areas - LaSalle-Grundy, Bureau-Putnam, Henry No. 6, Northern Knox, Vermilion, Logan, Macon, S.E. Montgomery, Macoupin, Madison, Bond, Clinton, Marion, Washington, Randolph, Perry, and Saline. The Central Illinois Light Company serves Peoria and Fulton-Knox General Areas. The Central Illinois Public Service Company serves the following General

Areas - Menard, Sangamon, Northern Christian, Clay, Wayne, Jefferson, Franklin, Jackson No. 5, and Williamson. The Union Electric Power Company serves part of the St. Clair General Area and, through facilities of Illinois Power Company, can reach the balance of the area.

All of the utilities have indicated that they would supply the plants if sufficient construction time is allowed and, in view of the desirable type of load involved, they probably would negotiate a rate lower than those now standard, as soon as definite plans for construction were made known.

Conclusions

Sufficient power for plant construction will be available for the local utility in each of the 31 General Areas. The power companies in the General Areas served by them, would doubtless be willing and able to provide power to a synthetic liquid fuels plant at very low rates.

Outside power would be required for starting up a coal synthine plant and for emergency stand-by purposes.

The magnitude of the installation required in a hydrogenation plant for handling process coal alone, together with the desirability of an outlet for the higher ash fractions of the washed coal, would usually make purchase of outside power disadvantageous. It seems advisable in the final consideration of a possible hydrogenation fuel plant in Illinois to carefully survey the exact quality and cost of coals available and to design the power plant with equipment to use such coal economically. Outside power sources are desirable as stand-by capacity.

The possible mutual advantages of integrating the electric generation of the proposed synthetic fuels plant into an existing power network should be given careful consideration.

ACCESS TRANSPORTATION

The construction and operation of a synthetic liquid fuels plant and its auxiliary coal mine facilities would, in general, require a direct rail or water connection, and a highway connection. Such services would be used during the construction period to move in the large volume of construction materials and plant equipment, and later, to transport plant and community supplies and some plant products. The latter may also be handled by pipe line as described in the section of this report pertaining to "Marketing".

Representative plant sites, consistent with topographic and geographic features of the General Areas, have been arbitrarily selected in order to prepare cost estimates. The selection of such points in the final analysis is arbitrary and is in no way intended to represent a recommended plant location.

Railroad facilities are well distributed in Illinois where a virtual network exists. The general terrain of the State is also such that access in any of the General Areas is readily obtained with very easy grading. Further, in very few cases, is a siding of any considerable length required in order to tie-in the General Area site with available railroad connection.

Railroad access is very necessary, but it is also important that highway access be assured for truck movement in and out of the plant, and transportation of personnel to and from the Area. Illinois is a rolling, relatively flat country, especially so in the sections where the General Areas are located. No formidable obstacles are therefore imposed with respect to highway construction, and the wide dispersion of the population and concentration centers, together with the location of Illinois on nationwide travel routes, results in a network of improved highways. Thus, no General Area is far removed from one of these improved highways.

Water access is afforded Illinois through the Illinois River Waterway, and the Mississippi and Ohio Rivers. However, the major portion of the plant areas are 20 miles or more from any of the available waterways, which with the provision of docking facilities and the requirement for an intermediate transfer and rehandling with the absence of general transportation service due to the restricted coverage of such waterways, would indicate inadvisability of considering any access transportation, other than rail or highway.

There are four Areas where water access might be considered with construction of docking facilities and access road required:

Area No. 2 - Plant site is approximately 3/4 mile north of the Illinois River.

Area No. 3 - Plant site is approximately 1/2 mile south of the Illinois River on top of a bluff.

Area No. 6 - Plant site is approximately 13 miles east of Lacon, Marshall County, on the east bank of the Illinois River.

Area No. 7 - Plant site is approximately 2 miles north of the Illinois River on top of a bluff.

The estimated cost of access facilities for each of the 31 General Areas in Illinois is given in the following table. Under the heading "General Area", the first item describes the required railroad facilities and the second item the required access highway facilities from the public paved highway system.

The amounts shown for railroad facilities under construction and operating costs are based on the assumption that the plants will bear full construction and maintenance costs of the required facilities. Operating costs are to provide for maintenance at an annual rate of 5 percent of the capital costs for such facilities.

In the case of access highway facilities, costs represent one-half the construction costs with no direct maintenance charges. It has been assumed that local governments would bear one-half the construction costs and maintain the

highways upon their completion. Under operating costs, the amounts charged against highway facilities are to provide for 40-year depreciation at an annual rate of 2.5 percent of the capital costs shown. Highway costs are based on a 20-foot highway of rough aggregate bituminous bound surface three inches thick on a 15-inch base course. Daily operating costs (railroads and highways considered separately) have been rounded to the nearest even dollar.

Estimated Cost of Access Facilities for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
1. Southeastern Grundy			
Approximately 2.5 miles from Gulf, Mobile & Ohio Railroad, south of Gardner; easy grading	$250,000	$12,500	$34
Lateral roadway 0.2 miles from improved road west out of Gardner	4,000	100	0
Total	$254,000	$12,600	$34
2. LaSalle- Grundy			
Chicago, Rock Island & Pacific Railway parallels the plant site area, east of Ottawa; access by plant facility siding connection	0	0	0
Lateral roadway, 0.2 miles from U.S. Highway 6, east of Ottawa	4,000	100	0
Total	$ 4,000	$ 100	$ 0
3. Bureau-Putnam			
Approximately 0.7 mile from Chicago, Milwaukee, St. Paul & Pacific Railroad, north of Moronts; moderate grading	$ 77,000	$ 3,850	$11
Approximately 3.7 miles improved of existing highway from Route 71 midway between Hennepin and Route 89 junction	46,000	1,150	3
Total	$123,000	$ 5,000	$14

Estimated Cost of Access Facilities
for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
4. Henry No. 6			
Approximately 0.4 miles from Chicago, Burlington & Quincy Railroad, southwest of Kewanee; easy grading.	$ 40,000	$3,000	$ 5
Approximately 0.4 mile improved of existing road from hard-surfaced road south from Kewanee	5,000	125	0
Total	$ 45,000	$2,125	$ 5
5. Northern Knox			
Approximately 0.5 mile from end of Galesburg & Great Eastern branch track at Victoria; easy grading	$ 50,000	$2,500	$ 7
Improved Highway 167 parallels plant area	0	0	0
Total	$ 50,000	$2,500	$ 7
6. Marshall			
Approximately 1.7 miles from Atchison, Topeka & Santa Fe Railway at Toluca; easy grading	$170,000	$8,500	$23
Approximately 1.1 miles improved of existing road from Highway 17	14,000	350	1
Total	$184,000	$8,850	$24
7. Peoria			
Approximately 0.4 miles from Toledo, Peoria & Western Railroad east of Glassford; easy grading	$ 40,000	$2,000	$ 5
Approximately 0.5 miles improved of existing road from Highway 176	6,500	163	0
Total	$ 46,500	$2,163	$ 5

Estimated Cost of Access Facilities
for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
8. Fulton-Knox			
The Minneapolis & St. Louis Railway parallels the plant site area, west of Middle Grove; access by plant facility siding connection	0	0	0
Lateral roadway, 0.3 mile across railroad track from Highway 116	$ 5,500	$138	$ 0
Total	$ 5,500	$138	$ 0
9. Vermilion			
Approximately 5/8 mile from Wabash Railroad, C & EI interchange connection, south of Catlin; easy grading	$62,500	$3,125	$ 9
Lateral roadway, 0.8 mile from improved highway south from Catlin	$14,000	$ 350	$ 1
Total	$76,500	$3,475	$10
10. Logan			
Approximately 0.5 mile from Gulf, Mobile & Ohio Railroad southwest of Lincoln; moderate grading	$70,000	$3,500	$10
Improved Highway U.S. 66 abuts the plant area	0	0	0
Total	$70,000	$3,500	$10
11. Macon			
Approximately 2.3 miles from Illinois Central Railroad, near Warrensburg; easy grading	$230,000	$11,500	$32
Approximately 2.0 miles improved of existing road from Highway 121	25,000	625	2
Total	$255,000	$12,125	$34

Estimated Cost of Access Facilities
for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
12. Menard			
Approximately 0.8 mile from Chicago & Illinois Midland Railway west of Petersburg, near Hilltop, easy grading	$80,000	$ 4,000	$11
Improve approximately 1.0 mile of road from Petersburg, assuming necessity to widen cut north of town	25,000	625	2
Total	$105,000	$4,625	$13
13. Sangamon			
Approximately 2.0 miles from Gulf, Mobile & Ohio Railroad south of Springfield, easy grading	$200,000	$10,000	$27
Highway U.S. 66 passes through plant area	0	0	0
Total	$200,000	$10,000	$27
14. Northern Christian			
Approximately 2.6 miles from Baltimore & Ohio Railroad south of Edinburg; easy grading with highway crossing	$260,000	$13,000	$36
Improve approximately 2.5 miles of existing road from Highway 29 at Edinburg with lateral roadway of approximately 0.3 mile	37,000	925	3
Total	$297,000	$13,925	$39
15. Southeastern Montgomery			
Approximately 5.5 miles from New York Central Railroad, south of Irving; moderate grading	$687,500	$34,375	$94
Improve approximately 5.5 miles of existing road from Highway 16, north of Irving	70,000	1,750	5
Total	$757,500	$36,125	$99

Estimated Cost of Access Facilities
for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
16. Macoupin			
Approximately 1.1 miles from Chicago, Burlington & Quincy Railroad, north of Litchfield; easy grading	$110,000	$ 5,500	$15
Improve approximately 40 miles of semi-improved road, north from Litchfield from U.S. Highway 66	50,000	1,250	3
Total	$160,000	$ 6,750	$18
17. Madison			
Approximately 3/4 mile from Illinois Terminal Railroad near Maple Crossing; easy grading	$ 75,000	$ 3,750	$10
Improve approximately 0.5 mile of existing road from U.S. Highway 66	6,500	163	0
Total	$ 81,500	$ 3,913	$10
18. Bond			
Approximately 1/4 mile from Pennsylvania Railroad near Stubblefield, southwest of Greenville; easy grading	$ 25,000	$ 1,250	$ 3
Improve approximately 0.4 mile of existing road from U.S. Highway 40	6,000	150	0
Total	$ 31,000	$ 1,400	$ 3
19. Clinton			
The Southern Railway parallels the plant area; access by plant facility siding connection	0	0	0
Highway 161 parallels the plant area	0	0	0
Total	0	0	0

Estimated Cost of Access Facilities for Each of 31 General Areas (As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Area			
20. Marion			
The Missouri-Illinois Railroad parallels the plant area, west of Robinett access by plant facility siding connection	0	0	0
Improve approximately 5.0 miles of existing unimproved road from U.S. Highway 51 north of Central City	$65,000	$1,625	$ 4
Total	$65,000	$1,625	$ 4
21. Clay			
The Baltimore & Ohio Railroad parallels the plant area, east of Clay City; access by plant facility siding connection	0	0	0
Lateral roadway 0.2 mile from U.S. Highway 50, east of Clay City	$ 3,500	$ 88	$ 0
Total	$ 3,500	$ 88	$ 0
22. Wayne			
Approximately 1/2 mile from Southern Railway, east of Merriam; moderately easy grading	$55,000	$2,750	$ 8
Lateral roadway, 1/4 mile from Highway 15	4,500	113	-
Total	$59,500	$2,863	$ 8
23. Jefferson			
Approximately 1-1/2 miles from Jefferson Southwestern (presently car use leased by Illinois Central and Missouri Pacific) at Nason; moderate grading	$188,000	$9,400	$26
Improve approximately 3.0 miles of existing unimproved road from Highway 37 at Ina	38,000	950	3
Total	$226,000	$10,350	$29

Estimated Cost of Access Facilities
for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Areas			
24. Washington			
Approximately 4 miles from Louisville & Nashville Railroad near Venedy Station west of Okawville; moderately easy grading	$440,000	$22,000	$60
Improve approximately 4.2 miles of existing road south from Highway 15 at Venedy Station	55,000	1,375	4
Total	$495,000	$23,375	$64
25. St. Clair			
The Southern Railway parallels the plant area, east of Shiloh Station; access by plant facility siding connection	0	0	0
Improved Highway 161 parallels the plant area	0	0	0
Total	0	0	0
26. Randolph			
The Gulf, Mobile & Ohio Railroad parallels the plant area, west of Sparta; access by plant facility siding connection	0	0	0
Highway 154 abuts the plant area	0	0	0
Total	0	0	0
27. Perry			
Approximately 1/4 mile from Missouri Pacific Railroad west of Pinckneyville; easy grading	$ 25,000	$1,250	$ 3
Improve approximately 3/4 mile of existing unimproved road from Highway 154	12,000	300	1
Total	$ 37,000	$1,550	$ 4

Estimated Cost of Access Facilities for Each of 31 General Areas
(As of March 31, 1950)

Description of Facilities	Capital Cost	Annual Operating Cost	Daily Operating Cost
Number and Designation of General Areas			
28. Franklin			
Approximately 0.8 mile from Illinois Central Railroad near Odum Spur, northeast of Benton, easy grading	$80,000	$4,000	$11
Improve approximately 0.9 mile of existing unimproved road from Highway 14	13,500	338	1
Total	$93,500	$4,338	$12
29. Jackson No. 5			
Approximately 1/2 mile from Missouri Pacific, west of De Soto; easy grading	$50,000	$2,500	$ 7
Improve approximately 1 mile of existing unimproved road from U.S. Highway 51 at De Soto	12,500	313	1
Total	$62,500	$2,813	$ 8
30. Williamson			
The Illinois Central Railroad parallels the plant area in the township of Corinth; access by plant facility siding connection	0	0	0
Improve 7.3 miles of unimproved road from Highway 34, approximately 2 miles west of Galatea	$92,000	$2,300	$ 6
Total	$92,000	$2,300	$ 6
31. Saline			
Approximately 1/4 mile from Louisville & Nashville Railroad, south of Eldorada, easy grading	$25,000	$1,250	$ 3
Improved Highway 142 parallels the plant area	0	0	0
Total	$25,000	$1,250	$ 3

LABOR

General

Determination of the labor force available to a proposed new synthetic liquid fuels unit plant involves a detailed study of the number of workers existing in and around the proposed location together with their characteristics, the nature of their present employment, the extent of unemployment, and the extent to which the proposed new plant would divert existing employment from present industry to itself. Personnel requirements of the proposed plant would then be compared with results of the detailed study to determine the size of the area containing sufficient available labor to satisfy the needs of the plant. Determination of the level of wages to be paid in a unit plant involves consideration of the wage level in such an area prevailing among existing industries comparable to synthetic liquid fuels as regards the skills and experience required of workers.

In this report, such studies by particular locations were not made. Instead, data on the number and composition of the labor force in the State and in the coal counties, data on unemployment both in the State and coal counties, and data on average wages prevailing in selected industries in the State were developed. Conclusions were drawn from such data as to the availability of labor and as to the prevailing level of wages in an average location in the coal counties, which were applied uniformly to the General Areas within the State.

Population and Employment Characteristics

The State of Illinois had a population density of 141.2 per square mile in 1940. The 1940 census showed a total population of 7,897,241, of which 5,809,650, or 73.6 percent lived in urban areas.

The 1950 census preliminary count shows the population of the State,as of April 1, 1950, to be 8,684,513 and the density of population at that time at 155.2 per square mile.

The 31 General Areas of Coal and Water Availability in Illinois as described in the preceding section of this report entitled "Coal", occupy part of or all of the 43 counties tabulated below:

Bond	Grundy	Macoupin	St. Clair
Bureau	Henry	Madison	Saline
Christian	Jackson	Marion	Sangamon
Clay	Jasper	Marshall	Shelby
Clinton	Jefferson	Menard	Stark
Edwards	Kankakee	Montgomery	Vermilion
Effingham	Knox	Peoria	Washington
Fayette	La Salle	Perry	Wayne
Franklin	Livingston	Putnam	Will
Fulton	Logan	Randolph	Williamson
Gallatin	Macon	Richland	

Details of the population characteristics, labor force, and employment categories for Illinois as a whole and for the coal counties are tabulated in Exhibit No. 29 and summarized below:

Population, Labor Force, and Employment
in Illinois and in the 43 Coal Counties

	Whole State (102 Counties)	Coal Area: 43 Coal Counties	Coal Area: Percent of State
Preliminary U. S. Census Data - 1950			
Area (square miles)	55,947	25,965	46.4%
Population	8,684,513	2,112,699	24.3
Density per Square Mile	155.2	81.4	
U. S. Census Data - 1940			
Population	7,897,241	1,996,922	25.3
Residing in Urban Areas:			
Number	5,809,650	985,487	17.0
Percent	73.6%	49.4%	
Labor Force	3,360,823	765,564	22.8
Employed Number	2,874,431	636,049	22.1
Percent of Labor Force	85.5%	83.1%	
Occupations of Employed Labor Percent of Total:			
Agriculture	9.9%	19.8%	44.2%
Mining	1.7	6.7	86.7
Construction	4.1	4.1	22.4
Manufacturing	28.6	21.6	16.7
Service	55.7	47.8	19.0

The coal counties had a 1950 population density of 81.4 per square mile. Data for the coal area as compared with State data indicates that in 1940, relatively fewer people lived in urban areas, relatively fewer people were employed, relatively fewer people were engaged in manufacturing and service, while greater numbers were engaged in agriculture and mining.

Estimated Labor Force. In Illinois, the total labor force, based on the 1940 census, has previously been stated as 3,360,823. If the labor force has increased proportionately to that of population, the 1950 labor force would be 3,695,862. The labor force of the coal counties on the same basis would be 809,950 or an average of 31,194 per 1,000 square miles in these coal counties.

The occupations of over three-quarters of the labor force in the State (workers covered by Federal Old-Age and Survivors Insurance) are indicated by the following tabulation. These workers include employes of an employer with as few as one employe.

Workers Covered by Federal Old-Age and Survivors Insurance as of Mid-March 1948

Industry Group Mid-March 1948	Total State		43 Coal Counties	
	Total	Percent	Total	Percent
Agriculture, Forestry, and Fishing	3,274	0.1%	801	0.2%
Mining	47,070	1.8	34,122	7.8
Contract Construction	116,426	4.4	20,280	4.7
Manufacturing	1,232,514	46.4	186,418	43.0
Public Utilities	166,542	6.3	26,797	6.2
Wholesale Trade	206,235	7.8	23,741	5.5
Retail Trade	480,476	18.1	88,979	20.5
Finance, Insurance, and Real Estate	144,936	5.4	12,535	2.9
Service Industries	253,252	9.5	38,635	8.9
Other (A)	5,615	0.2	1,477	0.3
Total	2,656,340	100.0%	433,785	100.0%

Note: (A) Includes groups not elsewhere classified and unclassified.

The remaining one-quarter of the total labor force (disregarding the increase from mid-March 1948 to April 1, 1950) were not covered and consisted of employes of government, railroads, certain non-profit organizations, agricultural, domestic and unpaid

family workers, those self-employed, and those unemployed. These workers generally, except some of the unemployed, are of types that do not now have the training or skills required for operation of synthetic liquid fuels plants.

From the above tabulation, it may be seen that in the State as a whole, 46.4 percent of the covered employes are engaged in manufacturing and 1.8 percent in mining, whereas in the coal counties the corresponding percentages are 43.0 in manufacturing and 7.8 in mining.

The number of workers engaged in manufacturing in the entire State of Illinois, as shown in the above tabulation, is further broken down by industry groups, as shown in Exhibit No. 30. While group totals are available for all counties in the State, individual industry figures are available for only 10 counties in the coal area (Kankakee, Knox, LaSalle, Macon, Madison, Peoria, St. Clair, Sangamon, Vermilion, and Will), which are also shown by 10 county totals on Exhibit No. 30. These 10 counties employ almost 80 percent of manufacturing labor in the coal area.

Seasonal Trends in Employment. Employment of workers covered by the Illinois Unemployment Compensation Law, as shown in the following table for a typical recent period of 13 months, is generally steady throughout the year, showing little seasonal variation. The monthly percentage of numbers employed based on the average of the months shown, varies from about 3 percent above to about 3 percent below such an average.

Workers Covered by Illinois Unemployment Compensation Law

Month	Monthly Employment (Thousands)	Percent of Average
1948		
June	2,398	102.7%
July	2,364	101.2
August	2,375	101.7
September	2,400	102.7
October	2,401	102.8
November	2,399	102.7
December	2,395	102.5
1949		
January	2,310	98.9%
February	2,277	97.5
March	2,263	96.9
April	2,274	97.3
May	2,254	96.5
June	2,254	96.5
Average	2,336	100.0%

Workers affected by this law exclude employes of government, railroads, certain non-profit organizations, agricultural, domestic and unpaid family workers, and the self-employed. Employes of an employer with less than 6 employes in any 20 weeks are also excluded, but the number of such employes is small.

Technical Training. Illinois is an industrialized State containing a large number of technically trained workers. Manufacturing activity has increased greatly since the last war, due in large part to the introduction of munition manufacture and expansion of machinery manufacture. The wartime gain in employment was accounted for both by hiring of women and by in-migration of workers from southern states. Most of these women have returned to their peacetime activities but the in-migrants have largely remained. Male workers during wartime, were intensively trained in technical skills both in war plants and in military service.

The number of workers, who were engaged (as of mid-March 1948) in industries employing workers of skills comparable to those required in operating and maintaining synthetic liquid fuels plants, is indicated by the following table (selected from the industry groups shown on Exhibit No. 30), which table also includes workers in electric and gas utilities.

Industries Employing Workers of Skills Comparable to Those Required by Synthetic Liquid Fuels Plants

	Workers Covered by Old-Age and Survivors Insurance	
	Entire State	10 Coal Counties (A)
Manufacturing:		
Chemicals and Allied Products	46,058	8,047
Products of Petroleum and Coal	17,139	9,445
Rubber Products	6,076	-
Primary Metal Industries	106,896	17,243
Fabricated Metal Products	129,263	5,592
Machinery (except electrical)	208,582	15,876
Electrical Machinery, etc.	129,566	3,675
Transportation Equipment	53,973	931
Total in Manufacturing	697,553	60,809
Electric and Gas Utilities	30,979	2,448
Total in All Selected Industries	728,532	63,257

Note: (A) Kankakee, Knox, LaSalle, Macon, Madison, Peoria, St. Clair, Sangamon, Vermilion, Will.

Unemployment

Unemployment varies from one area to another, dependent on local conditions. For a particular area, a survey of conditions prevailing in the area would have to be made to determine its extent. In this report, however, studies by particular areas were not made. Instead, as a measure of the extent of unemployment in the coal counties, the percentage of unemployed workers covered by State unemployment insurance to average covered employment in the State was tabulated by months for the years 1947 to 1949, inclusive, and the first two months in 1950. These percentages were taken from Bulletin of the Bureau of Employment Security of the U. S. Department of Labor and plotted in the form of a graph, as shown in Exhibit No. 31.

Unemployment varied between about 2 and 4 percent in the years 1947 and 1948, with an average during those years of about 3 percent. During 1949 and the first two months of 1950, however, unemployment increased sharply and reached a peak of about 7 percent in January 1950. The average unemployment for the 12-month period ended in February 1950 was 6.0 percent.

Estimated Total Unemployment. Application of the 6.0 percent of unemployment to the total estimated labor force in 1950 of 3,695,862 would indicate a total number of unemployed in the entire State of Illinois of 221,752. On the same basis, the unemployed in the coal counties would be 48,579, or 1,872 per 1,000 square miles.

Unemployed Skilled Labor. Assuming that the 6.0 percentage of unemployment in Illinois applies equally to the 728,532 workers in the industries employing skilled labor (as well as to the total labor force), then the unemployed skilled labor force in the entire State would be 43,712.

Workers in industries employing skilled labor in 10 of the coal counties have been shown to number 63,257. The number of such workers in the entire 43 counties comprising the coal area, assuming them to be in the same proportion as the number of manufacturing employes in the 43 counties (186,418) to that in the 10 counties (147,091) are estimated to be 80,170. By application of the same 6.0 percentage of unemployment, the unemployed skilled labor force in the coal counties would be 4,810 or 185 per 1,000 square miles.

Personnel Requirements of a Typical Synthetic Liquid Fuels Unit Plant in Illinois

Total Personnel Requirements. The total requirements of personnel to operate and maintain a typical synthetic liquid fuels plant in Illinois, to produce all the coal necessary as a raw material for the plant from mines owned or associated directly with the synthetic liquid fuels plant, and to supply the service requirements of such workers and their families, are shown in the following tabulation for the two processes using coal:

Total Personnel Requirements of a Unit Plant

	Coal Hydrogenation	Coal Synthine
Unit Plant Employes	1,175	1,135
Coal Mine Employes	759	995
Total Production Employes	1,934	2,130
Service Workers	1,779	1,960
Total Personnel	3,713	4,090

The numbers of unit plant employes shown above are those estimated by the U.S. Bureau of Mines for plants using the two processes as shown on the Plant Requirement Sheet Exhibit No. 71.

The numbers of coal mine employes shown above are those required to produce sufficient coal per annum to meet the fuel requirements of an average unit plant, using heating values and productivities per man-day at the average of those shown for the 31 General Areas in Illinois in the section of this report entitled "Coal". Development of such numbers of employes is shown in the following tabulation:

Total Number of Coal Mine Employes Necessary
To Produce Fuel Requirement of a Unit Plant in Illinois
(Average of 31 General Areas)

	Coal Hydrogenation	Coal Synthine
Daily fuel requirement of a unit plant in billions of Btu	98	126
Heating value of coal in Btu per pound, average of 31 General Areas	11,050	11,050
Annual fuel requirement of a unit plant in tons of Coal, average of 31 General Areas	1,618,552	2,080,995
Number of working days per annum in coal mines (assumed)	240	240
Productivity, tons per man-day of operational coal mine employes, average of 31 General Areas, each General Area weighted by number of years of operation using strip and underground coal	10.26	10.06
Number of operational coal mine employes working daily	657	862
Number of operational coal mine employes absent due to accident, illness, etc. 10%	66	86
Total number of operational employes	723	948
Administrative employes, 5% of operational	36	47
Total coal mine employes	759	995

The numbers of service workers shown above are 92 percent of the total production employes. Such workers and the relation between them and production employes are defined in a succeeding section of this report entitled "Housing and Community Development".

Skilled Plant Personnel Required. The U. S. Bureau of Mines estimates that 80 percent of the technical workers in synthetic liquid fuels plants can be trained from inexperienced local labor. A maximum of 20 percent must then consist of workers already possessed of skills or experience required in such plants. The requirements of skilled personnel are tabulated below for the two processes using coal:

Skilled Personnel Requirements of a Unit Plant

	Hydrogenation	Coal Synthine
Unit Plant Employes	235	227

It was considered that no particular difficulty would be encountered in obtaining the necessary skilled labor for mining operations.

Diversion of Presently Employed Labor. If a unit plant consuming large amounts of coal were to be introduced into an area already containing a large coal mining industry its requirements of coal may be presumed to have a profound effect on the economy of the industry, at least within the county or General Area in which the plant is to be located. It may reasonably be presumed that existing coal mines in the area will be able and willing to divert a portion of their present capacity (at least all of their marginal business) to supplying the unit plant at a price competitive with the cost of production in an associated mine and probably better than that now received by marginal business. Thus, a portion of the total personnel requirements of a unit plant may be satisfied by diversion of the productivity of existing coal miners in the area surrounding the plant, to the use of the plant. The diversion of as much as the total coal requirement of one unit plant in Illinois (a maximum of 2,080,995 tons in the case of an average synthine plant) would represent a diversion of only 3.2 percent of the 1948 coal production in the 43 coal counties of Illinois (64,924,131 tons). Such a diversion for one General Area could easily be made up by an increase in production of 3.3 percent in the remaining 30 General Areas. This increased production could be accomplished without additional manpower by working the mines only 7-1/2 days more per year over the average of 228 days worked in 1948.

New Personnel Requirements. When a new industry is introduced in a community its requirement for workers in excess of that portion met by the diversion of existing production to the new industry, must be satisfied either directly or indirectly by

recruiting of new workers; directly from workers who are not now employed, or indirectly from workers who will leave their present employment to work in the new industry and whose places must in turn be filled by recruiting from the ranks of the unemployed. An estimate of the number of new workers required by a unit plant is shown in the following tabulation:

Total Requirements of New Personnel for a Unit Plant in an Average General Area

	Coal Hydrogenation	Coal Synthine
Unit Plant Employes	1,175	1,135
Coal Mine Employes	512	746
Total Production Employes	1,687	1,881
Service Workers	1,552	1,731
Total Personnel	3,239	3,612

The numbers of new plant employes are the same as those previously indicated under "Total Personnel Requirements." Since no such plant as the unit plant exists in the General Area the total personnel requirements, including skilled workers, are new and must be filled either directly or indirectly by unemployed workers.

The numbers of new coal mine employes are estimated to be those required to supply the fuel requirements of an average unit plant on the same basis as used in developing the total personnel requirements but with the following assumptions regarding diversion of production of existing mines in an average General Area:

(a) That production of existing mines be brought to the capacity possible by working 240 days per annum (the same as that assumed in an associated mine) with the added production diverted to the unit plant.

(b) That one-fifth of the present (1948) production in an average General Area be diverted from its existing market to the unit plant.

(c) That the balance of production required by a unit plant will be produced in an associated mine working 240 days per annum.

The estimated number of coal miners required is developed in Exhibit No. 32.

Service workers are estimated at 92 percent (service to production worker ratio previously explained) of the new production workers required. It is logical to assume that service workers would be reduced in proportion to the reduction in production workers made possible by diversion of marginal coal production to the plant and the use of more working days per year.

Comparison of Personnel Requirements of a Unit Plant and Unemployment

The extent to which the new personnel requirements of a unit plant are met by the unemployed labor in the area surrounding the plant in an average location in the coal counties of Illinois is indicated by the following tabulation.

Comparison of New Personnel Requirements of a Unit Plant and Unemployed per 1,000 Square Miles in Coal Counties of Illinois, and Size of Area Containing Sufficient Unemployed to Satisfy Requirements.

Description and Process	New Personnel Requirement of a Unit Plant	Unemployed per 1,000 Square Miles	Size of Area Containing Sufficient Unemployed To Satisfy Requirement	
			Sq Miles	Radius-Miles
Total Personnel				
Hydrogenation	3,239	1,872	1,730	23.5
Synthine	3,612	1,872	1,929	24.8
Skilled Personnel				
Hydrogenation	235	185	1,270	20.1
Synthine	227	185	1,227	19.8

The above comparison indicates that in the coal counties of Illinois the personnel requirements of an average unit plant for total personnel could be satisfied by the numbers of unemployed in an area of from about 23 to 25 miles radius from the plant. Similarly, the requirements of skilled personnel could be met within a radius of about 20 miles. It is considered that such conditions indicate an ample supply of labor to be available to an average unit plant in Illinois to meet the personnel requirements both in total and in respect to skilled labor.

On the basis of a total number of unemployed persons in the entire State of Illinois of 221,752 and of a maximum personnel requirement per unit plant (using the synthine process) of 4,090, there would be sufficient workers to support 54 unit plants in the State.

Prevailing Wage Rates

The average straight-time hourly rate, as of March 31, 1950 paid in Illinois to wage earners (exclusive of supervisors) in industries similar to synthetic liquid fuels plants as regards the skills and experience required of workers has been estimated at $1.72. Since there exists in Illinois an adequate and suitable labor force, this estimated average wage rate is considered that payable in such a plant.

Should a second unit plant be introduced within about 50 miles of the first plant, it is probable that there would not be sufficient labor available locally to staff the plant and associated mine development and to supply the required service workers. Introduction of such a second plant would require recruiting of labor from outside a 25-mile radius from the plant and might necessitate increasing labor rates in order to attract workers from greater distances.

Basis of Estimated Wage Rates. Wage rates of workers of the higher skills to be employed in synthetic liquid fuels plants are governed by the rates paid in the chemical, petroleum refining, and coal mining industries, as such workers will have to be recruited from or paid in competition with them. Wages of workers of lesser skills, however, are not dependent to the same extent on wages paid in the above industries, but are governed by wages paid in the manufacturing industries presently existing in the areas in which the proposed plants are to be located.

In estimating wage rates in the synthetic liquid fuels industry, wage rates in the chemical, petroleum refining, and coal mining industries in relation to other widespread industries has been taken at a ratio of two to one. By dividing the number of workers (exclusive of supervisors), shown by the U. S. Bureau of Mines personnel classification for a 30,000-barrel-per-day coal hydrogenation plant, into two groups as to relative skills (above or below a wage rate of $1.70 per hour) a ratio of approximately two to one is shown as follows:

Ratio of Wage Earners of Higher Skills to Those of Lower Skills

Department	Number of Wage Earners		
	Higher Skilled	Lower Skilled	Total
Operating	955	139	1,094
Maintenance	807	484	1,291
Indirect	22	288	310
Total	1,784	911	2,695
Ratio of wage earners of higher skills to those of lower skills	1,784	÷ 911 =	1.96

U. S. Bureau of Labor, Wage Rates by Regional Areas. Wage Survey Bulletins prepared by the Bureau of Labor Statistics of the U. S. Department of Labor, as of various dates, were used as a basis for development, by regional areas, of wages paid in industries similar to synthetic liquid fuels plants. After adjustment to a uniform date, March 31, 1950, the average straight-time hourly rate, exclusive of premium, for the Great Lakes States (which include Illinois) has been developed for selected industries.

The industries selected as representative in each group of required labor skills are those for which there are available Wage Survey Bulletins covering all areas in the United States. Development of average straight-time hourly wage rates, exclusive of premium, made in the Great Lakes States is shown in the following tabulation.

Average Straight-time Hourly Wage Rates, Exclusive of Premium, Paid in Selected Industries in Great Lakes States
(As of March 31, 1950)

Industry	Hourly Wage Rate
Industries employing workers of higher skills:	
Chemical	$1.56
Petroleum refining	1.91
Bituminous coal mining	1.86
Average straight-time hourly earnings, weighted by reported total number of workers	$1.77
Industries employing workers of lesser skills:	
Fabricated structural steel	$1.41
Paints and varnishes	1.36
Ferrous foundries	1.49
Machinery	1.59
Fertilizers	1.17
Electric and gas utilities	1.56
Average straight-time hourly earnings, weighted by reported total number of workers	$1.56
Average straight-time hourly earnings combined by means of a weighting ratio of two to one of wages paid by industries using workers of higher skills to those using workers of lesser skills	$1.70

Wage Rates in Illinois. The straight-time average hourly wage rate, exclusive of premium, as developed for the regional area was then broken down to individual states by assuming that the ratio of the State rates to the area rate would be the same as that indicated by other wage studies such as: (a) that made by the Army-Air Force Wage Board, in 1948; (b) the Old-Age and Survivors Insurance Program during the first quarters of 1948 and 1947; and (c) the State Unemployment Insurance Program for the year 1946. This determination for the State of Illinois is shown in the following tabulation.

Straight-time Average Hourly Wage Rates, Exclusive of Premium, Paid in Selected Industries in Illinois
(As of March 31, 1950)

	Hourly Rates as Per Source of Information		Hourly Rates Adjusted to Level of Synthetic Fuels Industry	
	Regional Area	Illinois	Regional Area	Illinois
Army-Air Force Survey	$1.45	$1.39	$1.70	$1.63
OASI Program:				
1st Quarter 1948	1.62	1.65	1.70	1.73
1st Quarter 1947	1.47	1.48	1.70	1.71
Unemployment Insurance Program:				
Year 1946	1.39	1.38	1.70	1.69
Average Straight-time Hourly Earnings - Illinois				$1.69

It is the practice in manufacturing industries operating on a round-the-clock basis to pay a differential, or premium, to workers on the second and third shifts over hourly wages paid workers on the first shift. The differentials most prevalent in petroleum refining and bituminous coal mining are 4 cents per hour on the second shift and 6 cents per hour on the third. Assuming an equal number of workers on the three shifts in synthetic liquid fuels plants the average amount of shift differentials is 3 cents per hour. This amount is added to the average straight-time hourly wage rate (exclusive of premium) of $1.69 to give the hourly straight-time wage rate of $1.72 paid in selected industries similar to synthetic liquid fuels plants as regards the skills and experience required of workers.

HOUSING AND COMMUNITY DEVELOPMENT

Population Characteristics

The State of Illinois has a 1950 population density of 155.2 per square mile. Of the entire State population in 1940, 73.6 percent lived in urban areas. There are a number of large cities in Illinois; those with 1950 metropolitan area populations of over 100,000 are tabulated below:

Estimated Metropolitan Area
Population as of January 1, 1950

City	Population
Aurora	148,200
Chicago	5,261,300
Davenport, Iowa Rock Island, Ill. Moline, Ill.	233,900
Peoria	230,300
Rockford	135,800
Springfield	125,400

Source: Sales Management "Survey of Buying Power" - further reproduction not licensed.

In 43 coal counties of the State where General Areas for the location of synthetic liquid fuels plants are being considered, the 1950 density of population is 81.4. There are 45 cities of over 5,000 population within these counties ranging in size from 5,129 to 111,523. A tabulation of these cities and their preliminary 1950 populations follows:

Population of Cities of More Than 5,000 Inhabitants in the Counties Containing Available Raw Material

City	Preliminary Count 1950 Census	City	Preliminary Count 1950 Census
Alton	32,176	Lincoln	14,344
Belleville	32,701	Litchfield	7,211
Benton	7,837	Madison	7,960
Canton	11,910	Marion	10,130
Carlinville	5,129	Mendota	5,131
Centralia	13,814	Morris	6,917
Chester	5,388	Mt. Vernon	15,563
Collinsville	11,907	Ottawa	16,951
Danville	37,892	Pana	6,147
Decatur	67,801	Peoria City	111,523
DuQuoin	7,139	Peoria Heights	5,402
East Alton	7,311	Peru	8,691
East St. Louis	81,950	Princeton	5,737
Edwardsville	8,800	Salem	6,108
Fairfield	5,575	Springfield	80,832
Flora	5,250	Straetor	16,391
Galesburg	31,357	Taylorville	9,124
Granite City	29,139	Vandalia	5,480
Harrisburg	10,994	Venice	6,243
Herria	9,401	Washington Park	5,842
Hoopeston	6,019	West Frankfort	11,251
Kewanee	16,770	Wood River	10,217
LaSalle	12,023		

In these coal counties as of 1940, 49.4 percent of the population lived in urban areas, 27.8 percent in rural nonfarm, and 22.8 percent in rural farm areas.

Community Requirements and Population Determination

When a new manufacturing establishment is set up, unless it is located in an already established large community, it may be presumed necessary to develop an entire new community to house plant and associated workers conveniently near their place of employment to the extent that experience has shown it to be required.

Housing facilities alone, however, are not the only requisite of a new community. Residents of a new housing development require civic and commercial facilities reasonably convenient to their homes. It has been considered that such facilities must

be provided as an integral part of a planned community rather than allowing them to develop without plan on the outskirts of the development.

An estimate follows of the population of the plant-city associated with an average unit plant in Illinois based on numbers of plant and mine employes, together with associated service workers, for whom housing would be required. This estimate is based on average conditions in the coal counties of Illinois. It is subject to variation from one location to another, based on conditions existent in each individual location.

Population of 10,000-barrel-per-day Synthetic Liquid Fuels Plant-city

	Coal Hydrogenation	Coal Synthine
Plant and Mine Employes	1,265	1,467
Service Workers	1,164	1,350
Total Workers	2,429	2,817
Number of Households or Dwelling Units	1,868	2,167
Total Population To Be Housed	6,725	7,801

Number of Plant and Mine Employes To Be Housed. The percentage of plant and mine employes for whom housing would be required in a plant-city is based on a chart, Exhibit No. 33, which shows the "Ratio of Employes Housed in a Plant-city to the Relative Personnel Demand". This chart was developed from a study of the effect of density of population in the area surrounding existing communities, in which the predominant source of employment is one plant or factory.

The number of plant and mine employes estimated to be housed in the plant-city is shown in the following tabulation:

Number of Plant and Mine Employes Estimated To Be Housed

	Coal Hydrogenation	Coal Synthine
Population Density per Square Mile in Illinois Coal Counties	81.4	81.4
Population within 1,000 Square Miles (17.8 miles radius from plant)	81,400	81,400
Requirements of New Plant and Mine Personnel (from "Labor" section)	1,687	1,881
Above Requirements in percentage of Population within 1,000 Square Miles	2.07%	2.31%
Plant and Mine Employes To Be Housed in the Plant-city:		
Percent of Total (from Exhibit No. 33)	75%	78%
Number	1,265	1,467

Number of Service Workers To Be Housed. In every community, there must be service workers to minister to the needs of production workers. Such workers consist of proprietors and employes of wholesale and retail trade establishments, finance, insurance and real estate agencies, and a great variety of miscellaneous service establishments such as laundries, dry cleaners, barbers, shoe and hat cleaners and repairers, automobile repair shops, garages, motion picture houses, etc., as well as professional personnel such as doctors, lawyers, teachers, and governmental workers. Transportation and public utility workers are also considered as service workers for the purpose of this report. In sparsely settled rural counties, only the minimum services are provided in nearby centers, and the more specialized services must be secured in more distant trade centers. As mining or manufacturing expands in a community, trade and service establishments spring up within it over a period of time, and the number of workers in the service industries tends to equal the number in the production group, unless the community is a satellite of a large urban center. In estimating the service requirements of a plant-city in Illinois, it is considered that production workers living in the plant-city will receive the same degree of service as that prevalent in the coal counties. The percentage of service workers in terms of production workers is developed for the coal counties of Illinois in the following tabulation, as of 1940, based on data from Exhibit No. 29:

Percentage of Service Workers to Production Workers in Coal Counties of Illinois as of 1940

Class of Worker	Number	
Production		
Agricultural	125,586	
Mining	42,642	
Construction	26,258	
Manufacturing	137,554	
Total Production Workers		332,040
Service		
Total Service Workers		304,009
Percentage of Service Workers in terms of Production Workers		92%

Applying this percentage to the plant and mine employes estimated to be housed in the plant-city, the number of service workers to be so housed would be:

Estimated Number of Service Workers To Be Housed

	Coal Hydrogenation	Coal Synthine
Plant and Mine Employes	1,265	1,467
Service Workers - 92% of Plant and Mine Workers	1,164	1,350

Population of Plant-city. The number of employed persons per household may be determined for the State of Illinois, according to the 1940 census, as shown below:

Estimated Number of Employed Persons per Household as per 1940 Census

Employed Persons	2,874,431
Households	2,216,580
Employed Persons per Household	1.30

The Bureau of the Census shows, for Illinois in 1940, a population per household of 3.6.

Assuming these ratios to apply to the plant-city the total population is determined as below:

Estimated Total Population of Plant-city

	Coal Hydrogenation Process	Coal Synthine Process
Employed persons in plant-city	2,429	2,817
Households or Dwelling Units (employed persons divided by 1.30)	1,868	2,167
Total population (households multiplied by 3.6)	6,725	7,801

Estimates for this report have been based on the assumption of only one unit plant per 1,000 square miles. Simultaneous operation of two or more unit plants within such an area would require housing a substantially larger proportion of workers. This would entail increased investment in housing per plant with corresponding changes in operating costs.

Family Housing Requirements. In the past, common practice in construction of "company towns" has been to confine dwellings to those accommodating a single family. There is now, however, an increasing demand for multi-family or apartment dwellings. In this report, it has been assumed that 20 percent of all dwellings will be of this type, the balance being single homes. Analysis of single homes in existence in Oak Ridge, Tenn. in 1947 shows that about 75 percent had two bedrooms and 25 percent had three. For the purpose of estimating costs of the plant-city, the distribution by types of dwellings is assumed to be as follows:

Distribution by Types of Dwellings

Type of Dwelling	Percent of Total	Number of Dwellings for Plant-city of a Unit Plant: Coal Hydrogenation Process	Number of Dwellings for Plant-city of a Unit Plant: Coal Synthine Process
2-Bedroom single-family	60%	1,121	1,300
3-Bedroom single-family	20	374	434
Multi-family Units	20	373	433
Total	100%	1,868	2,167

Cost of Housing and Community Development for a Unit Plant

Investment in Plant-city. Based on the Contractor's experience in similar installations, a plan of a model city for employes of a synthetic liquid fuels plant was designed. This city plan provided housing, utilities, and civic and commercial facilities adequate for a population of 5,000 inhabitants. Cost estimates for such a model city were made at levels prevailing at December 1949, in the Pittsburgh, Pa., area.

From this estimate unit costs were developed for application to plant cities of populations estimated to be required in connection with unit plants in Illinois. An index of building construction costs applicable to the average location in General Areas of Illinois, as of March 31, 1950, as compared to similar costs in Pittsburgh, Pa., as of December, 1949, was developed based on data on construction costs as reported by The Dow Service, Inc. For Illinois, this index is 107.

The estimated investment required to construct a plant-city in connection with unit plants in Illinois is shown in the following tabulation for the two processes:

Cost of Housing and Community Development
Required for an Average Coal Hydrogenation Unit Plant
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 6,725 population at $9 per person	$ 60,525
Grading and Landscaping Site	
For 6,725 population at $162 per person	1,089,450
Dwelling Units	
1,121 - 2-Bedroom single-family at 806 sq ft at $9.82 per sq ft	8,872,715
374 - 3-Bedroom single-family at 988 sq ft at $9.82 per sq ft	3,628,548
373 - Multi-family at 850 sq ft at $8.96 per sq ft	2,840,768
1,027 - Garages (55% of Dwelling Units) at $867 each	890,409
Total Dwelling Units	$16,232,440
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 3,033,632
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	2,407,550
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	3,577,700
Total Investment for Complete Plant-city, exclusive of Water Supply	$26,401,297

Cost of Housing and Community Development Required for an Average Coal Synthine Unit Plant
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 7,801 population at $9 per person	$ 70,209
Grading and Landscaping Site	
For 7,801 population at $162 per person	1,263,762
Dwelling Units	
1,300 - 2-Bedroom single-family at 806 sq ft at $9.82 per sq ft	10,289,500
434 - 3-Bedroom single-family at 988 sq ft at $9.82 per sq ft	4,210,668
433 - Multi-family at 850 sq ft at $8.96 per sq ft	3,297,728
1,192 - Garages (55% of Dwelling Units at $867 each)	1,033,464
Total Dwellings	$18,831,360
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 3,519,208
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	2,792,758
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	4,150,132
Total Investment for Complete Plant-city, exclusive of Water Supply	$30,627,429

Commercial Facilities. It is recognized that, insofar as possible, an industrial plant-city, such as would be required by a synthetic liquid fuels plant, should be self-supporting. Commercial establishments and services, as an integral part of a community, are profit-making entities resulting from community development. Therefore, it has been considered that rental from commercial facilities would be ample to cover the charges on the investment in those facilities, including a proportionate share of the utilities and civic facilities and land. Such investment has been estimated as follows:

Allocation of Total Investment in Plant-city between Residential and Commercial Facilities, with Estimation of Appreciated Land Values

	Commercial	Residential	Total
For Unit Coal Hydrogenation Plant			
Capital investment	$3,577,700	$16,232,440	$19,810,140
Percent of total	18%	82%	100%
Allocation (based on percent of total) of:			
Utilities	546,054	2,487,578	3,033,632
Civic facilities	433,359	1,974,191	2,407,550
Investment in land improvements	$4,557,113		
Appreciated value of land, 1/6 of improvements	759,519		
Total commercial investment	$5,316,632		
For Unit Coal Synthine Plant			
Capital investment	$4,150,132	$18,831,360	$22,981,492
Percent of total	18%	82%	100%
Allocation (based on percent of total) of:			
Utilities	633,457	2,885,751	3,519,208
Civic facilities	502,696	2,290,062	2,792,758
Investment and land improvements	$5,286,285		
Appreciated value of land, 1/6 of improvements	881,048		
Total commercial investment	$6,167,333		

The advantages to management in the construction, operation, and control of its own city are recognized. Among them are:

(1) A more dependable and stable labor supply
(2) More desirable living conditions
(3) Better civic administration
(4) A cleaner and more orderly community
(5) Lower plant and community taxes.

Against these advantages, management will have the responsibility and expense of construction and administration of the plant-city. It is felt however that savings to the plant in municipal taxes will be sufficient to compensate for such expense.

Employe Home Ownership. The advantages of home ownership, both to the employes as individuals and to the company, are well recognized, and it is believed that some arrangement should be encourage whereby at least one-half the housing could be offered to employes on liberal terms, either directly by management or by reputable builders approved by management. The cost of the several types of housing including its share of land and utilities (but excluding civic facilities) and the bare cost of a garage are estimated for unit plants as follows:

Estimation of Residential Housing Costs

	Coal Hydrogenation	Coal Synthine
Cost of land, grading, and landscaping	$1,149,975	$1,333,971
Less allocation to commercial facilities	759,519	881,048
	$ 390,456	$ 452,923
Cost of utilities allocated to residential	2,487,578	2,885,751
Residential share of land and utilities	$2,878,034	$3,338,674

	No. of Units	Total Cost of Dwelling Units	Allocated Cost of Share of Land and Utilities	Residential Cost Total	Residential Cost Per Unit
Coal Hydrogenation:					
Dwelling Units-					
2-Bedroom single-family	1,121	$ 8,872,715	$1,664,445	$10,537,160	$ 9,400
3-Bedroom single-family	374	3,628,548	680,685	4,309,233	11,522
Multi-family	373	2,840,768	532,904	3,373,672	9,045
	1,868	$15,342,031	$2,878,034	$18,220,065	$ 9,754
Garages	1,027	890,409	-	890,409	
Total Residential		$16,232,440	$2,878,034	$19,110,474	
Coal Synthine:					
Dwelling Units-					
2-Bedroom single-family	1,300	$10,289,500	$1,930,188	$12,219,688	$ 9,400
3-Bedroom single-family	434	4,210,668	789,871	5,000,539	11,522
Multi-family	433	3,297,728	618,615	3,916,343	9,045
	2,167	$17,797,896	$3,338,674	$21,136,570	$ 9,754
Garages	1,192	1,033,464	-	1,033,464	
Total Residential		$18,831,360	$3,338,674	$22,170,034	

If one-half the dwellings of each type were sold at cost to its occupant then the remaining investment in dwellings and civic development would be:

Estimated Remaining Investment in Dwellings and Civic Development for Unit Plant

	Coal Hydrogenation	Coal Synthine
Total Investment for Complete Plant-city	$26,401,297	$30,627,429
Less:		
Commercial Facilities and Related Costs	$ 5,316,632	$ 6,167,333
One-half Cost of Housing Sold to Occupants	9,555,237	11,085,017
Total	$14,871,869	$17,252,350
Balance of Investment in Land, Dwelling Units, Garages, Utilities, and Civic Development	$11,529,428	$13,375,079

This balance of investment consists of dwellings not sold to employes, together with the investment in land, grading, utilities, and civic facilities not recovered by rental of commercial facilities or sold. This investment would be operated by the plant.

Operating Costs

The annual costs of operation of investment not recovered by rental of commercial facilities or by sale are estimated below:

Annual Operating Costs

	Coal Hydrogenation	Coal Synthine
Net Total Investment	$11,529,428	$13,375,079
Operating Costs @ 6%	691,766	802,505

Annual costs of operation are estimated to comprise in terms of annual percentages on investment:

Annual Costs of Operation
in Terms of Annual Percentage on Investment

	Percent
Depreciation (40-year life)	2.5%
Maintenance Costs	2.0
State and County Taxes, Insurance and Operation of Municipal Facilities	1.5
Total Annual Percentage	6.0%

It is considered that costs of operation of housing and community development may be recovered by rents of dwelling units without the necessity of any charge to plant operations.

The average amount per month required to offset operating costs would be $61.75 as shown below:

	Coal Hydrogenation	Coal Synthine
Annual Operating Costs	$691,766	$802,505
Number of Rental Units	934	1,083
Average per Unit:		
Annual	$741	$741
Month	$61.75	$61.75

Such an amount would be 15.9 percent of the average income per household of $4,651. The average annual wage of plant workers in Illinois has been estimated at $1.72 per hour or $3,577.60 per annum (of 2,080 hours). The average income per household on this basis would be $4,651($3,577.60 x 1.30 wage earners).

Return on Investment

Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per month for each unit, per day, and per barrel of products which would be required for each increment of 1 percent (before income taxes) on the estimated net total investment in housing and community development associated with unit plants in Illinois.

Incremental Costs for Each 1 Percent Gross Return on Initial Net Investment in Housing and Community Development

	Coal Hydrogenation	Coal Synthine
Initial Net Investment entitled to Return	$11,529,428	$13,375,079
1 Percent Return on Above:		
Per Annum	$115,294	$133,751
Per Dwelling Unit:		
Per Annum	123	123
Per Month	10.25	10.25
Per Calendar Day	316	366
Per Barrel of Products	$0.032	$0.037

The monthly rental to be paid by the occupant would be the average monthly operating cost plus the required return on the investment.

MARKETING

General

The agreement under which this report was prepared requires the General Areas suitable for the location of synthetic liquid fuels plants to be arranged in groups of relative desirability, with at least 2,000,000 barrels of daily production in the most desirable group for the total United States. This is equal to 730,000,000 barrels annually, or approximately 36.3 percent of the total demand for liquid fuels in the United States for the year 1949.

Motor Fuel - Major Plant Product. If a substantial part of the demand for liquid fuels in the United States were supplied by synthetic plants, the principal product would be motor gasoline.

Plants Using Coal or Natural Gas. For plants using coal or natural gas as raw materials, motor gasoline would be the major plant product. The amounts of motor gasoline specified to be produced from these raw materials by the various processes are as follows:

Percentage of Motor Gasoline
Specified To Be Produced by the Various Processes

Process	Percent
Hydrogenation	72.2%
Synthine Using Coal	72.8
Synthine Using Natural Gas	91.5

Plants Using Oil Shale. In the case of shale-oil plants, for the purpose of this report, motor gasoline is not specified as one of the products to be produced although such plants, if so designed, could produce motor gasoline. For a 10,000-barrel unit shale-oil plant, the principal products specified are 5,150 barrels of jet fuel and 3,350 barrels of Diesel fuel daily. The annual production of Diesel fuel of such a plant would be 1,220,000 barrels. In the year 1948, total sales of Diesel fuel in all of the Mountain States amounted to only 5,209,000 barrels. In other words, about five shale-oil plants would have been sufficient to satisfy the total demand for Diesel fuel in the Mountain States in that year. In the case of jet fuel, the annual output of a single 10,000-barrel-per-day shale-oil plant would be 1,880,000 barrels. This is approximately equal to the total sales of jet propulsion fuel, in the year 1948, of 1,891,000 barrels in the total United States. Consequently, it appears that if a relatively large number of synthetic liquid fuels plants should be established, the principal product would be motor gasoline. Furthermore, since it appears that only

enough natural gas will be available for relatively few synthetic liquid fuels plants, motor gasoline would amount to approximately 75 percent of the total productive capacity, based upon the plant product specifications.

From the foregoing, it is evident that of the total 2,000,000 barrels of daily productive capacity (which is equivalent to the capacity of 200 10,000-barrel synthetic liquid fuels plants) required to be included in the most desirable group of General Areas, gasoline would amount to approximately 1,500,000 barrels daily or 547,500,000 barrels annually. This would be 62.3 percent of the total United States demand for motor gasoline in 1949, which amounted to 878,887,000 barrels. If the total demand for motor Gasoline in 1949 had been supplied by synthetic liquid fuels plants, a total of 321 such plants would have been required. This is a relatively small number in contrast to the several thousands of plants potentially possible based on raw materials available.

Estimated Future Liquid Fuel Requirements. While the hazards of a long-range forecast of liquid fuel consumption are well recognized, it has been considered necessary in this present study to attempt to estimate probable liquid fuels requirements over the next 25 years because the usual short-term forecasts of a few years' duration would have little significance in appraising the economic factors that may have a bearing on the bringing into existence of a long-range program, such as the development of a synthetic liquid fuels industry. On the basis of present-day factors affecting motor gasoline consumption, the future demand has been projected by states and from this the total demand for the United States has been estimated, as shown in Exhibit No. 34, which demand in 1975 amounts to approximately 59 billion gallons, or 1.4 billion barrels annually. If this demand were met entirely with synthetic motor gasoline, the equivalent of 511 plants each of 10,000 barrels daily capacity would be required.

In recent years, the proportion of motor gasoline to the total demand for liquid fuels in the United States has averaged approximately 40 percent. At the present time, there are several factors which indicate that the motor gasoline percentage may rise in the next few years. There is a tendency for the percentage of residual fuel oils to decline as refining operations are altered. Furthermore, it is expected that the expansion of the natural gas industry may reduce relatively the consumption of fuel oil and kerosene. On the other hand, there may be some counterbalancing factors, such as the increasing use of jet propulsion fuel and Diesel fuel. However, on the basis of motor gasoline consumption of 40 percent, the total United States demand for liquid fuels in 1975 would be of the order of 3.5 billion barrels annually.

In order to provide a check upon the reasonableness of this estimate, the total annual energy supply for the United States was studied and projected to 1975. This is shown on the chart, Exhibit No. 35, which indicates estimated total energy requirements in 1975 of 50 thousand trillions of Btu. In a recent study, "Energy Uses and Supplies, 1939, 1947, 1965", by the U.S. Bureau of Mines,

Information Circular 7582, energy supplies in the United States are projected at approximately 48 thousand trillions of Btu in 1965. This is in close agreement with the 47 thousand trillions of Btu for 1965 shown on the chart, Exhibit No. 35. Of the estimated total energy supply in 1975 of 50 thousand trillions of Btu, the 3.5 billion barrels of liquid fuels would constitute 42 percent as contrasted with 35 percent in 1948, as shown on the chart, Exhibit No. 36. The relative proportions of energy supplied by coal, natural gas, and petroleum, which are also shown on that chart, indicate the reasonableness of the estimate. Some studies of liquid fuel demand have estimated that consumption in 1975 may be of the order of 5 or 6 billion barrels. If these quantities are related to the estimated 1975 total energy requirements, they would amount to 60 percent and 72 percent respectively. Such high percentages would appear to assume an unreasonable limitation on the use of other fuels such as coal and natural gas.

Crude Oil Reserves and Production. As of December 31, 1949, the estimated proved reserves of crude oil in the United States stood at 24,649,489,000 barrels, which is an all-time record high. This amount is 13.6 times the crude oil production of 1,818,800,000 barrels in 1949. If the proved reserves of natural gas liquids are added to the crude oil reserves, the estimated proved reserves of liquid hydrocarbons as of December 31, 1949 amounted to 28,378,501,000 barrels. In the past, new discoveries and extensions of old fields have added to the known supply. The following tabulation shows the amount of crude oil added to the supply by 5-year periods from 1925 to 1949:

Amounts of Crude Oil Added to the Supply

Period	Billions of Barrels
1925-29	10.044
1930-34	3.325
1935-39	12.161
1940-44	9.296
1945-49	13.336
Total	48.162

The above tabulation shows that, when the incentive has been strong, substantial quantities of crude oil have been discovered. It must be anticipated that further substantial quantities of oil will be discovered in the future. Recent important oil discoveries in Scurry County, Tex., and in California have increased appreciably the optimism with respect to future oil discoveries. Furthermore, the major oil discoveries made in Alberta, Canada, in recent years indicate that vast oil resources may exist in western Canada. This has led to the belief that important oil resources also may be found in North Dakota. In fact, the oil companies have under lease in the United States more than 200 million acres of untested lands, having geological formations considered favorable to the discovery of oil.

Based upon the estimate of future requirements of liquid fuels in 1975, as previously developed, crude oil production during the next 25 years would be required in the amount of approximately 62 billion barrels. This may be compared to the 48.2 billion barrels added to the supply in the 25-year period 1925 to 1949. Stated in other terms, the estimated crude oil requirements during the next 25 years are at about the rate of additions to the supply developed in the 5-year period 1945 to 1949. Through 1949 the total amount of crude oil produced in the United States amounted to approximately 39 billion barrels. This, together with the estimated requirements to 1975, would indicate a total cumulative production by that time of approximately 100 billion barrels. In recent years it has been variously estimated that the total amount of oil ultimately recoverable from primary onshore operations amounts to approximately 110 billion barrels. In addition, it is estimated that approximately 40 billion barrels more might be obtained from offshore operations and from secondary recovery. In the petroleum industry, it is generally estimated at present that less than half of the oil originally in place is produced. Important changes in methods of production, therefore, might add considerably to the recoverable supply.

Order of Desirability Influenced by Markets. Since there are some 25 states having Suitable General Areas, it is not possible in these separate state reports, which are being prepared seriatim, and not simultaneously, to contemplate all of the factors to be developed in subsequent state reports, which might tend to vitiate some of the material presented herein. It might be shown subsequently, for example, that markets allocated to nearby General Areas could be supplied more economically from synthetic liquid fuels plants located in other distant states. In any case, the determination of the order of desirability of the General Areas must take into consideration the cost of transporting products to a designated market that could absorb the assumed output and not be based solely on estimated fob. plant costs. In these state reports, markets are defined and allocated to the General Areas under consideration with the full realization that information subsequently developed may show that the markets could be served more economically by other potential synthetic liquid fuels plants.

Definition of the Marketing Territory

As shown on Exhibit No. 10, there are 31 Suitable General Areas of Coal and Water Availability in Illinois, located principally in the central and southern parts of the State. The neighboring States of Indiana, Kentucky, Missouri, and Iowa also contain Suitable General Areas for the production of synthetic liquid fuels. A determination of the potential markets for the major products of synthetic liquid fuels plants in Illinois must, therefore, give consideration to the limiting factors placed upon the market by the existence of potential plant sites in neighboring states.

The estimated costs of producing synthetic liquid fuels in each of the neighboring states have not been determined precisely at this time, but it appears from available factors that such costs in Indiana and western Kentucky will not differ sufficiently from those in Illinois for synthetic liquid fuels to move into those two states from potential plants in the Illinois General Areas. It appears desirable, therefore, to establish limits to the marketing territory to be served from synthetic liquid fuels plants in Illinois, on the assumption that there will be no cross haul of products between synthetic liquid fuels plants in Illinois and those in Indiana and western Kentucky. In the case of Missouri and Iowa, however, indications are that the estimated cost of producing synthetic liquid fuels may be so high that markets in those states might be served more economically from potential synthetic liquid fuels plants in Illinois or western Kentucky. Nevertheless, in order to avoid allocating markets to the synthetic liquid fuels plants of more than one state, neither Missouri nor Iowa is included at this time in the potential marketing territory for synthetic liquid fuels plants in Illinois.

No General Areas suitable for the location of synthetic liquid fuels plants are known to exist at this time in Wisconsin or Minnesota. Since Wisconsin borders on Illinois to the north, its requirements for liquid fuels may be considered as a potential demand on synthetic liquid fuels plants located in Illinois, especially in view of the excellent facilities which exist for the transportation of liquid fuels to that state from Illinois. While Minnesota does not border on Illinois, the Mississippi River could afford excellent means for transporting synthetic liquid fuels to the important markets in that state. Furthermore, while the estimated costs of producing synthetic liquid fuels in other states that might be regarded as potential sources of supply for Minnesota have not been determined precisely at this time, indications are that synthetic liquid fuels plants in Illinois would provide the lowest estimated costs delivered in the major markets in Minnesota. Consequently, the marketing territory to be served by potential synthetic liquid fuels plants in Illinois is defined as including the States of Illinois, Wisconsin, and Minnesota.

Consumption of Motor Fuel in the Marketing Territory

The major product specified to be produced from coal by both hydrogenation and synthine plants, as shown in a previous section of this report, is motor gasoline. For both processes, motor gasoline constitutes approximately 75 percent of the total productive capacity. Since this product constitutes such a high percentage of the total proposed output, extensive consideration has been given to the factors bearing upon the present and predicted future demand and the present and predicted future supply of motor gasoline.

Motor Fuel Consumption in Illinois. In this analysis, data on motor fuel consumption published by the Public Roads Administration have been used. In these figures, motor fuel consumption is reported for on-highway and off-highway uses, excluding sales to the Federal Government for military purposes. Consequently, military requirements are eliminated from consideration in this report.

The quality of gasoline proposed to be produced by both the hydrogenation and coal synthine plants is specified to be about 78 to 80 octane, motor method rating although it is recognized that there is some leeway in the processes, particularly the hydrogenation process, for producing some high-grade gasolines. Since this gasoline would be of lower standard than commonly used for aviation, aviation gasoline consumption has been eliminated from the total off-highway consumption of motor fuel as published by the Public Roads Administration. Therefore, motor fuel consumption figures given in this analysis do not include aviation use or purchases by the Federal Government for military purposes.

Motor gasoline consumption for the State of Illinois in the year 1948 amounted to 47,670,000 barrels. The annual production of motor gasoline from coal by a synthine or hydrogenation plant of 10,000-barrel-per-day capacity, would be approximately 2,737,500 barrels. Consequently, if the entire motor gasoline consumption in the State of Illinois in 1948 had been supplied by synthetic liquid fuels plants, approximately 18 such plants would have been sufficient to satisfy the total demand.

Since the motor fuel requirements of Illinois are well satisfied at the present time by petroleum products and since it appears that it may be many years before large quantities of synthetic liquid fuels will be required, it is desirable to estimate the future demand for motor fuel in Illinois. While ordinarily five or ten years might be considered the limit to which an estimate of future demand might be extended with a reasonable degree of accuracy, it was believed desirable in the present instance to attempt to estimate motor fuel consumption in the marketing territory to 1975. Even though the hazards of such long-range prediction are realized, the main purpose of the estimate is to indicate the probable maximum number of synthetic liquid fuels plants which would be needed were no petroleum liquid fuels available.

Future Consumption of Motor Fuel in Illinois. To make an estimate of the future demand in the State of Illinois, motor fuel consumption was divided into on-highway and off-highway uses. The estimate of future on-highway use of motor fuel was based primarily on the growth trends of population, motor vehicle registrations, and consumption per vehicle. The off-highway use was determined principally from the on-farm consumption.

Population. In general, the future population estimates were based on an estimate published, in November 1949, by the Bureau of Agricultural Economics of the U.S. Department of Agriculture. In the report, the population of the United States was projected to 1975 by major geographic divisions and the basis for these projections was past population figures of the Bureau of the Census.

The projections of future population by geographic divisions of the United States were based upon two estimates of future population by the Bureau of the Census. One of these, termed the high projection, was described as high fertility, low mortality, 200,000 net immigration per year, and high internal migration. The other, termed the low projection, was based upon medium fertility, medium mortality, no net immigration after 1950, and low internal migration. In this report, the high projection has been used since that forecast appears to be more reasonable, considering present population trends. On this basis, the population of the United States in 1975 is estimated by the Bureau of Agricultural Economics as 188,585,000.

Exhibit No. 37 shows the population by major geographic divisions of the United States from 1870 to 1950, with estimates to 1975. The extensions to 1975 on the chart correspond to the high projections made by the Bureau of Agricultural Economics, adjusted in the Pacific, Mountain, and South Atlantic States to reflect more recent conditions as indicated by the results of the 1950 Census. It should be noted that these extensions carry out the trends in the past and may provide a fairly accurate gauge of the population growth in the years to come.

Since the States of Illinois and Wisconsin are in the East North Central geographic division and the State of Minnesota is in the West North Central geographic division, the population of each state in these two divisions was studied both in absolute numbers and as percentages of the total population of the respective geographic division. From the percentage figures, projections of past trends were extended to 1975. The percentages so derived were then applied to the total estimated population of the geographic division in order to determine the population estimates of the various states. The figures so derived for the East North Central geographic division are presented in chart form in Exhibit No. 38 and for the West North Central geographic division in Exhibit No. 39. These exhibits show the population of each of the states in those two geographic division from 1900 to 1950 with estimates to 1975. The total estimated population in 1975 of the five states in the East North Central geographic division and of the seven states in the West North Central geographic division is equal to 38,377,000 and 15,653,000, respectively, which are the estimates for those geographic divisions prepared by the Bureau of Agricultural Economics. The population of Illinois as of April 1, 1950, was 8,712,176 and the estimate for 1975 is approximately 10,745,000, indicating an increase of approximately 23 per cent.

Motor Vehicles. To obtain an approximation of the number of automobiles likely to be in use during the next 25 years, data of past automobile registrations published by the Public Roads Administration were studied. The number of persons per private and commercial automobile registration in each state was calculated and projected to 1975. In making these projections, attention was given to effects of present and possible future population density, income per capita,, and other economic factors which would influence the number of persons per automobile.

Exhibit No. 40 shows the number of persons per private and commercial automobile plotted against income payments per capita, for each of the states of the United States in 1948. It will be noted that on this chart the number of persons per private and commercial automobile decreases as the income payments per capita increase, except in the most densely populated states. The lower limit appears to be about three persons per vehicle and this limit seems to be approached only in those states where the income payments per capita are high and where the population density is not high. These data were used as guides in projecting the future number of persons per private and commercial automobile in each of the states. Exhibit No. 41 shows the number of persons per private and commercial automobile in each state of the East North Central States for the years 1930 to 1949, with projections to 1975.

The number of persons per private and commercial automobile in the State of Illinois in 1948 was approximately 4.40. The estimate for 1975 is approximately 3.60 persons per private and commercial automobile. Using the future population estimates mentioned previously and this number of persons per automobile, the number of private and commercial automobiles in the State of Illinois in 1975 is estimated to be approximately 2,985,000, while the number in 1949 was approximately 2,050,000, an increase of about 46 percent. Exhibit No. 42 shows private and commercial automobile registrations in Illinois for the years 1927-1949 with estimates to 1975. The number of publicly owned automobiles in 1975 was assumed to bear the same relationship to private and commecial automobiles in that year as existed in 1948. On this basis, the total number of automobiles estimated for the State of Illinois in 1975, including both publicly owned and private and commercial vehicles, is 2,994,000.

The number of motor trucks likely to be in use in the State of Illinois by the year 1975 was estimated in much the same manner as that employed in calculating the number of automobiles. Consideration having been given to the main economic factors which would influence the growth in number of motor trucks, the number of persons per private and commercial truck was projected to 1975. The present and possible future conditions with respect to population density and income per capita were considered. Special attention was given to the number of farm motor trucks now in use in the various states, since farm motor trucks comprise approximately 29 percent of the total number of private and commercial trucks in the United States. A study was made of the size and number of farms in each state, and the potential number of farm trucks which could be supported was taken into consideration. With this and the other guides mentioned, the number of persons per private and commercial motor truck in each of the states was projected to 1975. Exhibit No. 43 is a chart which shows the number of persons per private and commecial motor truck in the East North Central States for the years 1930 to 1948 and estimates to the year 1975. An examination of this chart shows that the states have followed much the same pattern in the past years in regard to persons per private and commercial truck. From the future projection on this chart for the State of Illinois, the number of

persons per private and commercial truck in 1975 is shown to be 16.25. Using the population estimates developed previously and the same proportion of publicly owned motor trucks as existed in 1948, the total number of motor trucks expected to be in use was projected to 1975. In that year the estimate is 686,300 motor trucks as compared with 1948 registrations of 314,110 as reported by the Public Roads Administration. This is an increase of about 118 percent.

To estimate the growth in bus registrations, Public Roads Administration figures were used in conjunction with more recent figures obtained from the bus census of "Bus Transportation". From these data the number of persons per common carrier bus and per school bus were computed and projected to 1975. Using the population figures previously developed, the total number of buses for the State of Illinois was projected to 1975 with the number in that year amounting to approximately 12,000 buses.

On-highway Consumption of Motor Fuel in Illinois. To arrive at an estimate of future on-highway use of motor fuel the weighted average annual use of motor fuel per vehicle by type of vehicle was calculated from information of on-highway consumption for the State of Illinois published by the Public Roads Administration for 1948. The estimated future on-highway use of motor fuel in Illinois was then calculated from the number of motor vehicles previously estimated, multiplied by the weighted average annual consumption per vehicle. In other words, the estimates of future consumption are predicated on the average annual consumption per vehicle obtained in 1948. It is realized that motor vehicle efficiencies may increase somewhat in the future but data published by the Public Roads Administration covering vehicle travel per gallon of fuel consumed over the past 15 years would not indicate the likelihood of any striking changes in over-all efficiency. It may be that eventually motor vehicles will consume less fuel per vehicle-mile but it was believed preferable in this study to run the risk of overstating the future consumption rather than understating it by taking into consideration statements concerning future motor vehicle efficiencies that may not be achieved. If motor vehicle fuel efficiencies are increased appreciably in the future, the estimates of future on-highway consumption here developed will be proportionately too large. Based on the estimated number of vehicles and weighted average annual fuel consumption per vehicle, the on-highway motor fuel consumption in Illinois in 1975 is estimated at 2,999,352,000 gallons. This is an increase of approximately 70 percent over 1948 on-highway consumption of 1,761,420,000 gallons.

Off-highway Use of Motor Fuel in Illinois. Since the consumption of motor fuel in agriculture constitutes the largest single item of off-highway use, special attention was given to the consumption of motor fuel by tractors on farms. To estimate the number of farm tractors that will be required in 1975, the amount of crop land harvested per tractor was studied. Exhibit No. 44 shows in chart form the average crop land harvested

in acres per tractor for the United States from 1940 to 1949 with estimates to 1975.

To estimate the future number of tractors on farms for individual states, analyses were made of the number of farms by size groups, trends in the number of tractors on farms, the amount of crop land harvested in acres per tractor, per capita income payments, and the average amount of crop land harvested per farm. The chart, Exhibit No. 45 shows for each of the states in the United States for the year 1949 the average crop land harvested per tractor plotted against the average harvested crop land per farm. From the analysis of the number of farms by size groups, estimates were made of the maximum number of tractors which could be economically supported in each state. These numbers were then adjusted in view of the other factors mentioned above to arrive at an estimate of the number of tractors in each state. Using the estimated number of tractors in each state for 1975, the average crop land harvested per tractor was calculated and plotted against the average crop land harvested per farm, as shown in the chart, Exhibit No. 46.

The number of tractors on farms in the United States obtained for the year 1975 by totaling the individual state estimates developed as above amounts to 5,264,000 tractors. The reasonableness of the estimate of the number of tractors in each state in 1975 is indicated by the fact that the total for the United States (obtained in this manner) agrees quite well with the total estimated by the U.S. Department of Agriculture. In a study of food and harvested crop land required in 1975, the Department of Agriculture estimated that there would be 5,000,000 tractors on farms in the United States. That Department's estimate of the harvested crop land required, however, was based upon a lower estimate of future population than now appears reasonable. These estimates for tractors in 1975 may be compared to 3,365,000 tractors (excluding garden tractors) on United States farms as of July 1, 1949.

For the State of Illinois, the number of farm tractors in 1975 is estimated at 310,000. This is an increase of approximately 39 percent over the 223,240 tractors estimated on Illinois farms as of July 1, 1949. The amount of motor fuel consumed per tractor in each state in 1948 was obtained from information published by the Bureau of Agricultural Economics. These amounts were then multiplied by the estimated number of tractors in each state to arrive at estimates of future consumption of motor fuel by tractors in each state. For Illinois, motor fuel consumption by tractor in 1975 is calculated at 336,350,000 gallons.

Other off-highway uses of motor fuel in Illinois in 1948 represent only a small percentage of the total consumption and for purposes of this estimate are assumed to bear the same relationship in the future as in the past. The total motor fuel consumption in Illinois for the years 1927 to 1948 is shown on the chart, Exhibit No. 47, which also presents the estimate of future motor fuel consumption to 1975. It will be noted from the chart that the total motor fuel consumption (excluding aviation and military uses) for 1975 is

approximately 3,360,053,000 gallons or about 80.0 million barrels. This represents an increase of approximately 68 percent over 1948 consumption.

Number of Synthetic Liquid Fuels Plants Equivalent to Estimated Motor Fuel Consumption in Illinois in 1975. If there were no supplies of petroleum products available in 1975 in Illinois to satisfy the motor fuel requirements and if all the estimated future demand were supplied from hydrogenation or coal synthine plants, approximately 29 plants, each with a daily capacity of 10,000 barrels, would be required. This represents an increase of 11 synthetic liquid fuels plants over the number which would have been needed to supply the motor gasoline requirements for the State in 1948. It should be emphasized that the number of plants as given represents merely the maximum number, the output of which would be equivalent to the requirements for motor gasoline and makes no implication that that number of plants would be needed.

Motor Fuel Consumption in Wisconsin. Since the marketing territory of synthetic liquid fuels plants located in Illinois has been defined as including Wisconsin, it is necessary to analyze that market and to estimate its future magnitude. In this analysis, the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Illinois.

The population of the State of Wisconsin from 1900 to 1950 with estimates to 1975, is shown on the chart, Exhibit No. 38. As of April 1, 1950, the population of Wisconsin was 3,434,575 and the estimate for 1975 is 4,030,000, an increase of about 17 percent.

The number of persons per private and commercial automobile in Wisconsin is shown on the chart, Exhibit No. 41, with projections to 1975. In 1948, the number stood at 3.98 persons per private and commercial automobile and the 1975 estimate is 3.25 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 48, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 1,242,800 as compared with approximately 867,000 vehicles in 1949, an increase of about 43 percent.

On the chart, Exhibit No. 43, persons per private and commercial motor truck for Wisconsin are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 327,500 as compared with the total 1948 registrations of 207,572. Motor bus registrations in Wisconsin are expected to increase from approximately 3,500 in 1948 to approximately 4,580 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per motor vehicle by type of vehicle in 1948 for Wisconsin the total on-highway fuel consumption in Wisconsin in 1975 is estimated at 1,129,161,000 gallons. This represents an increase of almost 52 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed, the number of tractors on farms in Wisconsin is projected to 1975 and in that year is estimated at 230,000 as compared with 169,430 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in Wisconsin in 1975 is estimated at 167,900,000 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but excluding aviation and military use, is estimated for Wisconsin in 1975 at 1,317,814,000 gallons, or approximately 31.4 million barrels. This is an increase of approximately 51 percent over the total motor fuel consumption of 20,765,000 barrels in 1948. Exhibit No. 49 is a chart of total motor fuel consumption in Wisconsin for the years 1927 to 1948, with estimates to 1975.

Motor Fuel Consumption in Minnesota. Since the marketing territory of synthetic liquid fuels plants located in Illinois is defined to include Minnesota, it is necessary to analyze that market also and to estimate its future magnitude. In this analysis, the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Illinois.

The population of Minnesota from 1900 to 1950, with estimates to 1975, is shown on the chart, Exhibit No. 39. As of April 1, 1950, the population of Minnesota was 2,982,483, and the estimate for 1975 is 3,679,000, an increase of about 23 percent.

The number of persons per private and commercial automobile in Minnesota is shown on the chart, Exhibit No. 50, with projections to 1975. In 1948, the number stood at 3.68 persons per private and commercial automobile and the 1975 estimate is 3.17 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 51, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 1,163,700 as compared with approximately 862,000 vehicles in 1949, an increase of about 35 percent.

On the chart, Exhibit No. 52 persons per private and commercial motor truck for Minnesota are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 345,800 as compared with the total 1948 registrations of 173,564. Motor bus registrations in Minnesota are expected to increase from approximately 3,900 in 1948 to approximately 5,120 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for Minnesota, the total on-highway motor fuel consumption for Minnesota in 1975 is estimated at 1,034,961,000 gallons. This represents an increase of approximately 60 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed, the number of tractors on farms in Minnesota is projected to 1975 and in that year is estimated at 283,000 as compared with 202,000 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in Minnesota in 1975 is estimated at 254,700,000 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but excluding aviation and military use, is estimated for Minnesota in 1975 at 1,295,980,000 gallons or approximately 30.9 million barrels. This is an increase of approximately 58 percent over the total motor fuel consumption of 19,548,000 barrels in 1948. Exhibit No. 53 is a chart of total motor fuel consumption in Minnesota for the years 1927 to 1948, with estimates to 1975.

Number of Synthetic Liquid Fuels Plants Equivalent to Motor Fuel Consumption in the Marketing Territory

The following tabulation shows a summary of total motor fuel consumption, less aviation and military use, in the States of Illinois, Wisconsin, and Minnesota for the year 1948 and the estimates for 1975. The tabulation also presents the total motor fuel consumption for the marketing territory as defined, and the number of hydrogenation or coal synthine plants, the motor fuel productive capacity of which would be equivalent to the total motor fuel consumption in the marketing territory.

Motor Fuel Consumption and Equivalent Number of Unit Synthetic Liquid Fuels Plants

	Millions of Barrels				Equivalent Number of Unit Synthetic Liquid Fuels Plants
	Illinois	Wisconsin	Minnesota	Marketing Territory	
1948	47.67	20.77	19.55	87.99	32
1975 Est.	80.00	31.38	30.86	142.24	52

While it is indicated by the above tabulation that the output of motor fuel of 52 hydrogenation or coal synthine plants of 10,000 barrels daily capacity would be the equivalent of the estimated consumption in the marketing territory in 1975, it must be emphasized that it is not implied that this number of synthetic liquid fuels plants would be required. The calculation is made to show the maximum number of such plants that would be needed if no supplies of petroleum products were available, and for purposes of

comparison with the number of synthetic liquid fuels plants potentially possible, based upon the coal and water availability. As shown previously, these are sufficient to support approximately 237 hydrogenation plants or approximately 184 synthine plants.

Consumption of Liquid Fuel Products Other Than Motor Fuel in the States of Illinois, Wisconsin and Minnesota

Although motor gasoline is specified as the major plant product of both hydrogenation and synthine plants using coal as a raw material, other liquid fuel products and phenols are also specified to be produced. These are listed in the following tabulation, which shows the plant product distribution for both hydrogenation and coal synthine plants and also shows the other products as percentages of the proposed motor gasoline production.

	Unit Plant Product Distribution			
	Barrels per Day		Percent of Gasoline	
	Hydrogenation	Synthine Using Coal	Hydrogenation	Synthine Using Coal
Gasoline	7,220(A)	7,280	100%	100%
Diesel Fuel	-	1,900	-	26.1
Fuel Oil	-	350	-	4.8
Liquefied Petroleum Gases	2,367	470	32.8	6.5
Phenols	413		5.7	-
Total	10,000	10,000		

Note: (A) May be increased to 7,684 barrels per day of gasoline by conversion of phenols.

The actual consumption of liquid fuels in the States of Illinois, Wisconsin, and Minnesota, by principal product classifications, is presented in the following tabulation:

Liquid Fuel Consumption in the States of
Illinois, Wisconsin, and Minnesota
in the Year 1948 by Principal Product Classifications

Description	Thousands of Barrels		
	Illinois	Wisconsin	Minnesota
Motor Fuel	47,670	20,765	19,548
Kerosene	5,618	1,684	1,404
Diesel Fuel	4,418	1,363	1,147
Other Distillates	17,204	7,246	9,082
Residual Fuel	15,157	1,497	1,314
Total	90,067	32,555	32,495

In the above tabulation, the figures for motor fuel consumption are exclusive of aviation and military uses. The data given for the other product classifications are sales figures as published by the Bureau of Mines. Consumption or sales figures for liquefied petroleum gases are not published by states but are available by Petroleum Administration for War districts. The figures for District No. 2, which includes the States of Illinois, Wisconsin, Minnesota and 12 other states, show that sales of liquefied petroleum gases in the year 1948 amounted to approximately 5.9 percent of the motor fuel consumption in that district.

The following tabulation shows, for petroleum products similar to the products specified to be produced by synthetic liquid fuels plants, consumption in Illinois, Wisconsin, and Minnesota in 1948 as percentages of motor fuel consumption.

Consumption of Other Liquid Fuel Products
as a Percentage of Motor Gasoline Consumption

Description	Illinois	Wisconsin	Minnesota
Motor Gasoline	100.0%	100.0%	100.0%
Diesel Fuel	9.3	6.6	5.9
Residual Fuel Oil	31.8	7.2	6.7

The distribution of actual product consumption evident in the above tabulation differs materially from the proposed distribution of plant products specified to be produced by hydrogenation and coal synthine plants. In the case of Diesel fuel, the actual consumption amounts to 7.9 percent of the motor fuel consumption, whereas for synthine plants the estimated production is 26.1 percent. The output of liquefied petroleum gases by hydrogenation plants at 32.8 percent of the gasoline produced is unusually high

as compared with consumption in 1948 in P.A.W. District No. 2, which amounted to approximately 5.9 percent.

It is apparent from the above analysis that the plant product distribution for both hydrogenation and coal synthine plants does not correspond to actual product consumption in Illinois, Wisconsin and Minnesota. In the case of the hydrogenation type of plant, according to the proposed plant product distribution, too high a percentage of liquefied petroleum gases is specified, and in the case of the coal synthine plants the percentage of Diesel fuel specified is too high. Of course, if only a few synthetic liquid fuels plants were in operation, the differences would be immaterial, but if the entire amount of motor fuel requirements were to be supplied by either one or the other type of synthetic liquid fuels plants, the plants would have to be redesigned to approach more nearly the required product distribution. It appears, however, that complete reliance upon synthetic liquid fuels plants as a source of supply is so far in the future that the product demand pattern may change considerably in the intervening years. At such time as synthetic liquid fuels plants are economically feasible, it is probable that they would be so designed as to produce the products then in demand.

Sources of Liquid Fuels Supply for the Marketing Territory

Sources of Crude Oil. The State of Illinois is an important producer of crude oil, accounting for about 3.5 percent of the total United States production in 1949. In that year, Illinois produced approximately 64 million barrels of crude oil while proved reserves as estimated by the American Petroleum Institute stood at 468,138,000 barrels as of December 31, 1949. During 1949, there was no reported production of crude oil in the States of Wisconsin and Minnesota.

Although crude oil is produced in large volume in Illinois, the total production is not adequate to care for the total crude oil requirements in the marketing territory. The major portion of the crude oil originating in Illinois is shipped to refineries in other states with the consequence that refineries in the marketing territory obtain the bulk of their requirements of crude oil from other producing states. Receipts of crude oil at refineries in the marketing territory by states of origin in the year 1948 are shown in the following tabulation:

Receipts of Crude Oil at Refineries
in the Marketing Territory
By States of Origin in the Year 1948

States of Origin	Thousands of Barrels
Illinois	23,944
Kansas	17,675
Louisiana	1,199
New Mexico	2,904
Oklahoma	24,838
Texas	45,263
Wyoming	4,158
Other Receipts	1,931
Total Receipts of Crude Oil	121,912

Over 80 percent of the crude oil received at refineries originated in states outside of the marketing territory coming principally from Texas, Oklahoma, and Kansas. Furthermore, over 91 percent of the crude oil received was delivered by pipe line; with tank cars, trucks, and boats accounting for less than 9 percent of the total amount delivered. The following tabulation shows receipts of crude oil in refineries by method of transportation for the year 1948:

Receipts of Crude Oil at Refineries
in the Marketing Territory
By Methods of Transportation
in the Year 1948

	Thousands of Barrels
Intrastate Receipts:	
By Pipe Line	22,751
By Tank Car and Truck	1,193
Total Intrastate Receipts	23,944
Interstate Receipts:	
By Pipe Line	88,647
By Tank Car and Truck	8,664
By Boat	657
Total Interstate Receipts	97,968
Total Receipts:	
By Pipe Line	111,398
By Tank Car and Truck	9,857
By Boat	657
Total Receipts of Crude Oil	121,912

Crude Oil Refining Capacity. The present oil refining capacity in the marketing territory is approximately equivalent to its consumption of liquid fuels. As of January 1, 1950, the total refining capacity amounted to 154 million barrels of crude oil annually. This may be compared to the annual consumption of all liquid fuels in the marketing territory in 1948 which amounted to approximately 155 million barrels. Crude oil runs to stills in 1948, however, amounted to only 121 million barrels indicating that large amounts of petroleum products were shipped into the marketing territory from other states.

As of January 1, 1950, there were 22 oil refineries located in the marketing territory, 19 of which were in Illinois. A list of the refineries with their locations, crude oil capacities, and operating companies is given below:

Oil Refineries in Illinois
(As of January 1, 1950)

Location	Crude Oil Capacity (Barrels per Day)	Company
Blue Island	7,500	Great Lakes Refining Co.
Burnham	1,000	Calumet Refining Co. (Red River Refining Co.)
Centralia	2,500	Advance Refining Co., Inc.
Centralia	4,500	Arrow Petroleum Co.
Colmar	1,000	Henry H. Cross Co.
Dupo	1,000	Dupo Oil Refining Co.
East St. Louis	30,000	Socony-Vacuum Oil Co., Inc.
Fairfield	2,500	Sol-Tex Refining Co.
Hartford	25,000	Wood River Oil & Refining Co., Inc.
Lawrenceville	27,000	The Texas Co.
Lemont	31,925	Globe Oil & Refining Co.
Lockport	60,000	The Texas Co.
Pana	4,000	Pana Refining Co.
Plymouth	250	Wireback Oil Co.
Robinson	43,500	Ohio Oil Co.
St. Elmo	5,000	Northwestern Refining Co.
Salem	4,000	Harmony Oil Corp.
Wood River	115,000	Shell Oil Co., Inc.
Wood River	42,800	Standard Oil Co. (Ind.)
Total	408,475	

Oil Refineries in Wisconsin
(As of January 1, 1950)

Location	Crude Oil Capacity (Barrels per Day)	Company
Sheboygan	6,000	Wisconsin Oil Refining Co., Inc.

Oil Refineries in Minnesota
(As of January 1, 1950)

Location	Crude Oil Capacity (Barrels per Day)	Company
New Brighton	3,000	Northwestern Refining Co.
St. Paul Park	5,000	Northwestern Refining Co.
Total	8,000	

Sources of Refined Products. As indicated previously, the demand for liquid fuels in the marketing territory is now met principally by petroleum products produced in refineries located within the marketing territory. Nevertheless, there is a substantial movement of refined products into the marketing territory from other important refining centers. Refineries located in Indiana in the vicinity of Chicago, Ill. are an important source of products. There is also a substantial movement of products by barge up the Mississippi River into the marketing territory as far as Minneapolis from refineries located in Louisiana and Texas. In addition, there are several products pipe lines which supply important centers of consumption in the marketing territory from refineries located in the Mid-Continent area.

Prices of Petroleum Products in Illinois

Since the production of crude oil in Illinois is by no means sufficient to meet the requirements for liquid fuels in the marketing territory, the demand is met principally by the movement of crude oil and products from the West and Southwest. This movement from the important producing states requires a rather long haul and even though it is principally by pipe line, nevertheless transportation costs are sufficient to provide some competitive advantage to synthetic liquid fuels plants in Illinois due to being located in an important market relatively distant from the major sources of supply of petroleum.

In this study consideration has necessarily been given to the prices of petroleum products in Illinois as being one of the important factors affecting present and future demand for liquid fuels in the marketing territory. Weighted average composite prices of petroleum products have been computed based upon the same liquid fuel products and proportions as those specified to be produced by hydrogenation and coal synthine plants. These composite prices were constructed from quotations obtained on the various petroleum products in wholesale quantities fob. refineries in Illinois, excluding taxes. While the cost calculations for synthetic liquid fuels plants and products contained in other sections of this report are based upon prices and quotations prevailing as of March 31, 1950, it was deemed preferable to use, in these calculations, quotations for petroleum products as of June 1, 1950 because refinery margins as of that date, appear to have been more nearly normal. In the tabulation on the following page, prices of the various petroleum products in Illinois, as of June 1, 1950, are weighted according to the plant product distributions specified for hydrogenation and coal synthine plants.

In the tabulation referred to, the price shown for gasoline is that of regular grade house brand containing tetraethyl lead with an octane rating of 82 or better. This product is evidently superior as a motor fuel to the gasoline specified to be produced by the hydrogenation and synthine processes using coal. The gasoline produced by these processes is stated to have an octane rating of 78 to 80 motor method and no provision has been made in the calculations for the addition of tetraethyl lead although it is understood that such additions could be made at nominal cost above the base cost of the required tetraethyl lead. The quotation on Diesel fuel is for a product with a rating of 55 cetane. In the tabulation, the price used for fuel oil for the synthine process is that of No. 6 (residual fuel oil).

Propane is specified to be produced by the synthine process using coal and both propane and butane by the hydrogenation process in the proportions of about 72 percent propane and 28 percent butane. The price differential between propane and butane is subject to wide seasonal fluctuation. In the summertime, prices of the two products may be equal, but in the wintertime, when there is a demand for butane for mixing with motor fuel, the price may rise considerably above that for propane. In the calculations the price for propane alone is used since that product constitutes such a high percentage of the total.

Composite Prices of Petroleum Products Fob. Refineries in Illinois as of June 1, 1950
Weighted According to the Plant Fuel Product Distributions
Specified for Hydrogenation and Synthine Plants Using Coal

Product	Hydrogenation Plant Fuel Product Distribution (Percent)	Prices of Petroleum Products			Synthine Plant Product Distribution (Percent)	Prices of Petroleum Products		
		Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel		Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel
Gasoline	75.31%	12.00¢	$5.04	$3.796	72.80%	12.00¢	$5.04	$3.669
Diesel	-	-	-	-	19.00	9.50	3.99	.758
Fuel Oil	-	-	-	-	3.50	6.00	2.52	.088
Propane and Butane	24.69(A)	5.00	2.10	.518	4.70	5.00	2.10	.099
Total	100.00%			$4.314	100.00%			$4.614

Note: (A) 72 percent propane and 28 percent butane.

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In the tabulation referred to, the composite wholesale price fob. refinery of petroleum products as of June 1, 1950 weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation plants is shown to be $4.31 per barrel and for products weighted in the same proportions as those specified to be produced by coal synthine plants the composite wholesale price is shown to be $4.61 per barrel. It should be pointed out that the estimates of future demand for petroleum products have been based on projections of present-day factors affecting consumption. It is not known how or when synthetic liquid fuel products will become competitive with petroleum products in the marketing territory. If, due to difficulties in developing supplies, costs of crude petroleum rise to such an extent in the future as to cause petroleum product prices to rise substantially relative to the general price level and to alter the competitive price positions of fuels, the projected future demand may be considerably less than the amounts estimated previously for the marketing territory.

Transportation of Plant Products

When synthetic liquid fuels plants become economically feasible, they will occur first obviously in those General Areas where the over-all conditions appear most favorable for financial success. An important advantage of synthetic liquid fuels plants in certain Areas would be their proximity to markets made possible by raw material resources located in or near regions of high population density or to which the costs of transporting petroleum products are high. In such cases, the resultant lower costs of distributing plant products to the points of consumption within the marketing territory would give an important economic advantage to the local plants.

Synthetic liquid fuels plants situated in the Suitable General Areas in Illinois would be well located for the distribution of plant products within the marketing territory, whether the output of a single plant or of a number of plants is considered. A single plant in any one of the General Areas could probably dispose of its output within reasonable trucking distance of the plant, while a number of plants could make use of the excellent transportation facilities which already exist for the distribution of petroleum products within the marketing territory.

Many of the General Areas in Illinois are situated in regions of very high population density and near large urban centers. The southeastern part of the State, in which a few General Areas are located, has considerably lower population density than the other sections; nevertheless fairly large aggregations of population exist in the vicinity of each General Area. The estimated population of the counties in Illinois, by

size groups, as of January 1, 1949, is shown on the map, Exhibit No. 54. This exhibit also shows the approximate center of each General Area. During 1948, the average annual per capita consumption of motor fuel in Illinois was about 5.71 barrels. At that rate, 479,000 persons would consume the motor gasoline production of a single hydrogenation or coal synthine plant. It is clear from a study of the map, Exhibit No. 54, that sufficiently large populations live within reasonable trucking distance of most of the General Areas for the output of a single plant to be disposed of locally, if the products were distributed by one of the important marketers or if there were an exchange of products between companies. If it is assumed that single plants exist simultaneously in each of the General Areas, the products of all of them could not be marketed locally.

If a substantial part or all of the market's requirements for motor gasoline were to be supplied by synthetic liquid fuels plants, it would be desirable to utilize the existing excellent transportation facilities which serve the marketing territory. By the use of short pipe lines, plants in many of the General Areas could be connected into the products pipe line systems which provide for a rather flexible movement of products to the principal centers of consumption. Short product pipe lines could also be constructed from plants in several General Areas to bulk terminals on the Ohio and Mississippi Rivers. Barge movement on the Mississippi River as far north as Minneapolis would provide access to markets in western Illinois, western Wisconsin, and the major markets in Minnesota which lie in the southeastern part of the state. The Illinois River and Waterway which run in the vicinity of several General Areas provide a connecting link between the Mississippi River and Lake Michigan and would afford economical transportation of products into the Chicago area. Tank ships operating on Lake Michigan and Lake Superior would provide for the movement of products from terminals in the vicinity of Chicago to the important markets in eastern and northern Wisconsin and northern Minnesota.

The petroleum products pipe lines in existence in Illinois as of August 1, 1949 are shown on the map, Exhibit No. 55, which also shows the approximate center of each of the 31 General Areas. Plants in General Areas Nos. 1, 2, 3, 4, 5, 6, 7, and 8 would be well located to supply large markets in the vicinities of Chicago, Kankakee, Peoria, Galesburg, Rock Island and Moline. These could be tied into the Sinclair products pipe line by short pipe lines ranging in length from a few miles up to approximately 20 miles, depending upon the point of junction. Plants in several of these General Areas would also be well located for movement of products on the Illinois River and Waterway. In the region of these General Areas, the population density is so high that the consumption of liquid fuels would be equivalent to a large part of the potential synthetic liquid fuels capacity of these General Areas.

The Shell and Phillips products pipe lines which run from Wood River and East St. Louis on the Mississippi River to the vicinity of Chicago on Lake Michigan would be very accessible to synthetic liquid fuels plants located in any one of the General Areas, Nos. 10 to 19, inclusive, and No. 25. Short products pipe lines not exceeding 20 miles in length could connect the plants in these General Areas to one or the other of these pipe lines. Of these General Areas, Nos. 16, 17, and 25 are well located also for the movement of products to barge terminals on the Mississippi River.

Plants in General Areas Nos. 23, 24, 26, 27, 28, 29, 30, and 31 could be connected to barge terminals on the Ohio or Mississippi River by relatively short pipe lines for the movement of products to the important markets served by water movement. General Areas Nos. 9, 21, and 22 appear to be not as well located for the movement of products throughout the marketing territory. General Area No. 9 could be connected into either the Phillips or Shell pipe lines which run to the vicinity of Chicago by the construction of a pipe line about 60 miles in length. General Areas Nos. 21 and 22 could either be tied into the Shell products pipe line by the construction of a pipe line approximately 70 miles in length or they could be connected by pipe line into a pipe line from General Area No. 31 to the Ohio River.

All of the General Areas in Illinois, except possibly General Areas Nos. 21 and 22, appear to be well located for the distribution of their products either locally or throughout the marketing territory. General Areas Nos. 13, 14, 15, 16, 19, 25, 27, 28, and 31 which contain raw material resources for the largest number of potential synthetic liquid fuels plants are very well situated for the transportation of products throughout the marketing territory. While the northerly General Areas Nos. 1 to 8, do not have the large synthetic liquid fuels potential of many of the General Areas to the south, they are nevertheless very well located for the movement of products to large nearby markets.

The petroleum products pipe lines in the marketing territory as of August 1, 1949, which have not been considered previously, are located in the State of Minnesota, there being no products pipe lines in Wisconsin and are shown on the map, Exhibit No. 56. The Standard of Indiana products pipe line which runs from the vicinity of Chicago would provide economical transportation of products from certain of the northerly General Areas to the markets in Minneapolis and St. Paul and other important markets in southeastern Minnesota. This pipe line would also provide a means of transportation to the smaller markets in central and western Minnesota. There are at present very large terminal storage facilities at Minneapolis and St. Paul which are supplied by barges operating on the Mississippi River.

The products from synthetic liquid fuels plants could be moved to these terminals for pipe line movement within Minnesota. While the present flow of liquid fuels through the Great Lakes products pipe lines in Minnesota is to the north and northwest from refineries in the mid-continent area, if no petroleum products were available, these pipe lines could no doubt be rearranged for the distribution within Minnesota of products barged to Minneapolis and St. Paul from synthetic liquid fuels plants in Illinois.

In this report, no consideration is given to the possibility of using the presently existing crude oil pipe lines for the transportation of synthetic liquid fuel products. At such time as synthetic liquid fuels become commercially feasible, it might be possible to convert such crude oil pipe lines as are then in operating condition and conveniently located for the transportation of synthetic liquid fuel products.

The cost of transportation of plant products to the marketing territory is one of the factors that must be taken into consideration in determining the relative desirability of the General Areas suitable for synthetic liquid fuels plants. It has been shown previously that a single 10,000-barrel-per-day hydrogenation or coal synthine plant located in any one of the General Areas in Illinois could probably dispose of all or a major part of its output locally. In this regard, some of the General Areas are more favorably situated than others, being closer to large centers of consumption. General Areas Nos. 21 and 22 appear to be the only areas from which a part of the output might have to be moved beyond reasonable trucking distance. Except for this, products from each of the General Areas could probably be moved to bulk stations or to dealers by transport truck or tank truck. In this study, it is not considered feasible or necessary to measure the cost of transporting products to local distribution points or to dealers' premises.

In the case of a substantial number of synthetic liquid fuels plants operating simultaneously, delivery of products to the points of consumption would be by pipe lines, barges, and trucks. A large part of the cost of distributing products throughout the marketing territory would be incurred jointly and might not be segregable by plants. While the cost of transportation is one of the factors that must be considered in determining the relative desirability of General Areas, in this study, this requirement has been construed not to include the cost of moving products within the marketing territory. By definition, the marketing territory for plants located in the Suitable General Areas in Illinois was limited to the area in which it was assumed the local plants would have transportation cost advantages over synthetic liquid fuels plants located in states outside of the marketing territory. In other words, the transportation costs with which this study is concerned are those covering the movement of products to distant marketing

territories and not those incurred in distributing products to points of consumption within the defined marketing territory. It is assumed that the cost of distribution within a given marketing territory would be about the same for plants located outside as for those within the territory but that outside plants would incur additional costs of transporting products to the market under consideration. Consequently, in determining the relative desirability of General Areas, costs of transportation need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

Summary and Conclusions

For the purpose of analyzing potential markets for synthetic liquid fuels plants in Illinois, the marketing territory has been defined to include the entire market in the States of Illincis, Wisconsin, and Minnesota. Motor fuel consumption in this marketing territory in 1948 amounted to approximately 88 million barrels and is estimated to reach an annual volume of approximately 142 million barrels by 1975. These amounts of motor fuel consumption would be equivalent respectively to the gasoline output of about 32 and 52 synthetic liquid fuels plants of 10,000 barrels daily capacity using coal as raw material.

The plant product distributions specified for both the hydrogenation and synthine plants using coal do not correspond to the present actual product consumption in the marketing territory. If only a few synthetic liquid fuels plants were in operation, the differences would be inconsequential. If a substantial part of the motor fuel requirements, however, were to be supplied by one or the other of these processes, the plants would need to be redesigned to produce the products then in demand.

The demand for liquid fuels in the marketing territory is economically supplied at present principally by crude oil and products from the mid-continent and southwestern states and, to some extent, by crude oil produced locally. Wholesale prices as of June 1, 1950, of petroleum products fob. refineries in Illinois amount to $4.31 per barrel when weighted in the same proportion as the liquid fuel products specified to be produced by hydrogenation plants and to $4.61 when weighted according to the plant products specified for coal synthine plants. A major increase in liquid fuel prices, altering basically the competitive positions of fuels, could have the effect of reducing substantially the estimates of demand within the marketing territory.

In the United States during the 5- year period, 1945-1949, the amount of crude oil added to the known supply was larger than in any similar period; and furthermore, proved reserves as of December 31, 1949 stood at an all-time record high of about 25 billion barrels. During this 5-year period, proved reserves increased 4,864,959,000 barrels. From the analysis, the prospective supply of petroleum appears adequate to satisfy the demand for liquid fuels for the present and at least a major portion of future requirements for a long period of years.

When synthetic liquid fuels plants, using coal as a raw material, become commercially feasible, it appears likely that they will be constructed first in those General Areas where there is a combination of unusually favorable factors. An important advantage for synthetic liquid fuels plants in the eastern half of the United States would be their proximity to relatively large centers of consumption, where plant products doubtless would be largely distributed locally. In respect to Illinois, such plants, if situated in the several Suitable General Areas established in this report, would be well located for the distribution of plant products within the marketing territory whether the output of a single plant or of a substantial number of plants were to be marketed. Within the marketing territory defined, plants in the Illinois General Areas would have minimum costs for distribution of synthetic liquid fuels. For the purpose of determining the relative desirability of General Areas in the United States, costs of transportation of plant products need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

WASTE DISPOSAL

General

The manufacture of synthetic liquid fuels from coal, by either hydrogenation or synthine process, produces gaseous, liquid, and solid wastes, all of them constituting potential nuisances. Any or all of these may require special treatment or disposal in degree, depending upon the location of the plant with respect to settled communities, public water supply, farming areas, etc. The principal gaseous wastes are sulfur compounds, resulting from combustion or removal of sulfur present in the coal. Liquid wastes consist of waste water from process, carrying oil and chemical contamination; blowdown from cooling towers and boilers, which may carry excessive concentrations of dissolved solids; and plant sanitary sewage. Solid waste consists of ash originally present in the coal, any unburned coal, and spent catalysts, principally iron oxide.

Gaseous Wastes

In the coal hydrogenation process, about one-fifth of the coal consumption of the plant is burned in the boiler house. Sulfur dioxide is present in the flue gases to the same extent as in those from any other power plant of equivalent size (about 90,000 to 100,000 kw) in respect of boiler capacity. The sulfur present in the balance of the coal is removed at various points in the process, appearing as hydrogen sulfide. This may be burned in the power plant, producing additional sulfur dioxide in the stack gases; burned to sulfur dioxide and converted to by-product sulfuric acid, or converted directly to elemental sulfur, using currently established commercial processes. If burned in the power plant, the total sulfur dioxide resulting will be about equivalent to that from a very large steam power plant - say 500,000 kw. Choice of alternative disposal methods would depend on local markets for the respective by-products.

In the coal synthine process, the steam and power required are generated from waste heat. The coal received at the plant goes direct to synthesis gas manufacture, the sulfur in the coal appearing principally as hydrogen sulfide, which is removed in concentrated form in the course of gas purification. If necessary, hydrogen sulfide may be burned in flares, producing sulfur dioxide. In the case of high-sulfur coals, however, the quantity of hydrogen sulfide produced may be too great for such disposition. In such case, hydrogen sulfide may be converted to sulfuric acid or to elemental sulfur, the choice depending upon local markets for these by-products. In any event, it appears practicable to reduce the sulfur nuisance to any reasonable extent required.

Liquid Wastes

The principal contaminated liquid process waste discharged from a coal hydrogenation plant will be a relatively small amount - about 50,000 gallons per day - of foul process water, separated from the oil stream in the cold traps and pressure letdown tanks, and carrying relatively high concentrations (in the tenths of a percent) of dissolved phenols, ammonia, and hydrogen sulfide, as well as oil and tar in suspension. Industrial wastes containing phenols are of great importance because they impart serious tastes to drinking water supplies and, if in sufficient concentration, are toxic to fish and other aquatic life. Although the wastes from a synthetic liquid fuels plant would be treated or recovered either to eliminate the phenols or reduce them to a point where they would be harmless, it is recognized that occasionally, the treatment process might break down and that some phenols would reach the receiving stream. The effect of such possible discharges from the synthetic liquid fuels plants would depend upon the exact location of the plant and the distance from the point of discharge to the water-works intake or intakes.

Preliminary studies indicate that it will be possible to remove all of these contaminants to any extent which may be required by local health or other authorities, at a total cost well within the allowance already made for this purpose in the over-all plant construction and operating cost estimates. Subject to necessary further development work, it now appears that this removal can be accomplished by a series of operations consisting of:

(a) A skimming pond for gross removal of oil and tar;

(b) Liquid-to-liquid solvent extraction of remaining oil and tar, using hydrocarbon solvent cuts obtained in the main process and recycled;

(c) Pressure release, accompanied by heating, to remove hydrogen sulfide and ammonia;

(d) Treatment with recently developed highly basic ion-exchange resin, to effect phenol removal down to perhaps 0.005 ppm; followed by

(e) Final treatment with ozone to oxidize any remaining phenol below possible taste level, if necessary.

Periodic regeneration of the ion-exchange resin with concentrated caustic soda will produce a strong solution of sodium phenolate from which crude phenol may be separated by treatment with waste carbon dioxide from the main plant and returned to process. The small quantity of sodium carbonate solution remaining could be evaporated to dryness for ultimate disposal, if necessary. A rough preliminary estimate indicates that a total sum of $500,000 to .

$600,000 should be adequate to cover the cost of such a disposal system, including the oil-skimming pond.

It is also possible to destroy phenols by biochemical oxidation, as for example on a trickling filter. This method, which is practiced on a commercial scale in the United States, requires preliminary reduction of phenol concentration, either by solvent extraction ("phenosolvan"process) or by dilution, to about 200 ppm. The combined operation would be substituted for step (d), above. However, the possible presence, in the foul process water, of cyanides which may cause serious interference with bacterial action, has led to the consideration of ion-exchange as an alternative method.

In the case of synthine, side-reactions in the process together with scrubbing operations, result in a water stream containing large quantities of organic compounds, principally aliphatic alcohols, acids, aldehydes and ketones. Information from the U.S. Bureau of Mines, together with preliminary studies by other engineers in the petroleum industry who have worked on this problem, indicates that scrubbing may be limited to the point where total quantity of process and scrubbing water combined amounts to about 450,000-500,000 gallons per day in a unit plant. To the extent that a market can be found for the chemical by-products, they may be recovered and sold. However, after a few synthine plants have been established, it is anticipated that the existing market for such products in refined state would be saturated, with the result that their recovery would no longer be profitable. In such case it is assumed that a crude mixture of the more volatile alcohols and ketones will be removed by a simple distillation, and either sold at fuel value or returned to process for gasification to provide additional synthesis gas. The contaminated water remaining would be used as boiler feed to provide make-up steam for synthesis gas production.

Plant sanitary sewage from either hydrogenation or synthine plants would be of the order of 100,000 gallons per day in a unit plant. If local authorities require treatment before this effluent is run into the streams, the necessary sewage disposal plant should not involve an investment of more than $100,000 to $150,000.

Engineers of the U.S. Bureau of Mines have stated that the plant cost estimates, in the case of each process, include an allowance of approximately $1,000,000 to cover waste disposal from a unit plant. This should be sufficient to cover maximum requirements for complete treatment of contaminated liquid process wastes and plant sanitary sewage. Since over-all plant operating cost estimates are based primarily upon factors proportionate to construction cost, the inclusion of adequate construction cost provision for liquid waste disposal in the general estimates also implies inclusion of proportionate allowance for disposal system operating costs. The probable adequacy of this allowance is indicated by preliminary estimates. In respect of coal synthine, some

dissenting opinion exists as to whether the scrubbing water may be limited within the amount which can be re-absorbed in process. Any excess would require treatment before disposal. Further development work is necessary before the question may be resolved. At the worst, a disposal cost of $0.10 to $0.20 per barrel of products might be required, over and above the allowance already included in general process cost estimates.

The remaining liquid plant waste to be considered is that resulting from boiler and cooling tower blowdown. Since the principal water consumption in both hydrogenation and synthine processes is by evaporation loss, the water rejected from the plant, other than the process and sanitary wastes mentioned, will consist largely of these blowdowns and may contain the major part of the daily tonnage of dissolved solids in the gross water make-up drawn by the plant. As a result, the concentration of dissolved mineral salts in the blowdown water may be several times as great as that in the original make-up. For plant locations where the make-up water is not already abnormally high in dissolved salts, and where the wastes can be discharged into streams of which the minimum flow is large in proportion to the waste volume, dilution of the blowdown with other plant effluents should serve to keep the whole within acceptable limits. Where large quantities of blowdown are to be discharged into small streams having a low minimum flow, the increase in solids might affect the suitability of the water for other uses. Such uses are minor, and, in general, no difficulty should be encountered in the discharge of blowdown from cooling towers. In extreme cases, however, it is possible that State authorities may require a reduction in the concentration of dissolved solids before approval is granted. This may involve added costs, over and above those included in the general allowance for waste disposal. Actual determination of these added costs (if any) for any specific plant location would require detailed information, such as individual standards applying to the particular stream which would receive the wastes, complete analysis of the water available for cooling tower make-up and for possible dilution purposes, and similar data, not available in the current general survey.

Stream Pollution. In regard to possible stream pollution and the necessity for treatment of liquid wastes for plants in Illinois, the following conditions have been developed in the course of the investigation:

> If synthetic liquid fuels plants were built in Illinois, the State almost certainly would require that industrial wastes be treated, or otherwise limited in concentration and amount, and that the sewage from the communities built up in connection with such synthetic liquid fuels plants be treated. The degree of treatment would depend to some extent upon the quantity of waste and the location of the plant. Wastes discharged into large rivers would not require as complete treatment as wastes discharged into the smaller streams.

The domestic sewage could be treated by conventional methods to whatever degree is necessary. In any event, the cost of such treatment would be only a small part of the total cost for providing community facilities.

There are a good many small municipal water supplies taken from the streams in the coal regions of Illinois, and in selecting plant sites, care should be taken not to locate a synthetic liquid fuels plant immediately upstream to a water-works intake. In general, the small supplies with impounding reservoirs near the upper end of tributaries would be in no danger because the synthetic liquid fuels plants would more logically be located on larger streams. The principal water supplies that might be affected adversely by wastes from a synthetic liquid fuels plant are discussed briefly in the following paragraphs-

The city of Canton is in the southeastern corner of the Fulton-Knox General Area and derives its water supply from Copperas Creek. Otherwise, there are no municipal water supplies taken from surface streams in the General Areas along the Illinois River. In the Sangamon River Basin, Decatur (Macon General Area) takes its water from the Sangamon River and Springfield (Sangamon General Area) takes its water from Sugar Creek. A very small supply at Kincaid (Northern Christian General Area) is taken from the South Fork of the Sangamon River.

In the Macoupin General Area which is drained by Macoupin and Cahokia Creeks, tributaries of the Illinois and Mississippi Rivers, respectively, there are three small water supplies that might be affected by synthetic liquid fuels wastes. A small water supply at Grafton, taken from the Illinois River at its mouth, might also be affected by synthetic liquid fuels discharges from the plants in the Macoupin General Area or in Areas along the Illinois River. However, the amount of dilution in the Illinois River is so great that it is not expected that any difficulty would ensue. The Centralia water supply (Marion General Area) and 12 other municipal supplies in the Kaskaskia River Basin which use surface water for municipal purposes might be subject to wastes from synthetic liquid fuels plants located in the southeast Montgomery, Macoupin, Madison, Bond, Clinton, Marion, Washington, St. Clair, and Randolph General Areas. The Chester water supply, taken from the Mississippi River a short distance below the Kaskaskia River, might possibly be affected, but the dilution available is so great that there should be no serious consequences.

There are 12 municipal water supplies taken from the Big Muddy River and its tributaries which might be affected by synthetic liquid fuels wastes. The supply at West Frankfort, in the Franklin General Area, is the largest of these. The water supply

for Harrisburg, and one other small community in the Saline General Area which is taken from tributaries of the Saline River might be subject to waste pollution if plants were located upstream from them. The water supply for Danville in the Vermilion General Area in the eastern part of the State is taken from the North Fork of the Vermilion River, but except for one other small supply in the area, there are no water supplies that would be affected.

The discharge of wastes from a large-scale synthetic liquid fuels development on tributaries of the Wabash would jeopardize the water supplies of Terre Haute, Vincennes, and Mt. Carmel unless care was taken to remove practically all of the phenols before the waste was discharged into the river. Similarly, a major development in the Saline River basin might cause trouble to several municipal water supplies on the Ohio River, and a large-scale development in the western part of the State might affect some of the water supplies taken from the Mississippi River.

While the discharge of wastes into rivers immediately above water-works intakes would cause difficulty, the problem would not be very great in Illinois and could be handled at comparatively small cost. In some instances, it might be cheaper to replace small water-supply systems, rather than to locate a synthetic liquid fuels plant at some other point. The larger water supplies would generally be protected by dilution and oxidation of the phenols unless the synthetic liquid fuels plant were located within a few miles of the water-works intake.

Legal Aspects. The Illinois Sanitary Water Board is vested with authority: (1) to investigate methods for prevention of stream pollution that would be detrimental to public health, animal or aquatic life, or recreational uses; (2) to establish where pollution exists; (3) to order waste discharge discontinued unless adequate treatment works are provided. A permit from the Board is required for the construction of a sewage system or waste treatment works. Continuation of pollution after an order of the Board constitutes a nuisance which may be ordered abated by an action by the Attorney General.

No specific standards with regard to the disposition of sewage or phenolic wastes have been established, the policy of the Sanitary Water Board being to consider stream usage in each individual case. In no instance, however, would anything less than primary treatment of sewage be approved. Where downstream surface water supplies would be affected, the discharge of substantial quantities of phenolic wastes would not be approved.

The Illinois legislature has approved and enacted into law the Ohio River Valley Water Sanitation Compact for the control of stream pollution in the Ohio River basin. The Ohio River Valley Water Sanitation Commission created by the Compact is composed of three members from each of the participating states and three from the Federal Government. It is authorized to prescribe regulations and standards for administering and enforcing the Compact, although it is the policy of the Commission to leave the enforcement of pollution control measures primarily with state regulatory agencies. The Commission is authorized, however, to hold hearings and issue orders against pollution offenders when this action is desired by the signatory state in which the particular pollution occurs.

The Compact prescribes that sewage shall be treated to remove all settleable solids and 45 percent of the total suspended solids with a higher degree of treatment to be provided where deemed necessary by the Commission. The Compact also requires that all industrial wastes shall be treated to protect the public health or to preserve the surface waters for other legitimate purposes to such degree as may be determined to be necessary by the Commission. The Commission first met in 1948, and its requirements for industrial waste treatment have not been fully established. The Commission's policies will, however, influence the degree of treatment to be required for wastes from synthetic liquid fuels plants in Illinois.

Solid Wastes

Solid wastes of the order of 460 to 810 tons per day, consisting of coal ash, unburned coal, and spent catalysts, would be produced by a 10,000-barrel-per-day synthine plant operating on Illinois coal as raw material. A hydrogenation plant would produce in total about two-thirds of this amount, but in normal isolated plant locations about 45 percent of the ash may be dissipated from the power plant stack as fly-ash, leaving net ash quantity sent to disposal only about one-half of that from a coal synthine plant.

Cost of Solid Waste Disposal. The quantity requiring disposal is sufficient in either case to justify fairly elaborate mechanical handling and stacking in order to minimize labor cost. In the case of the coal synthine process, estimates prepared for this purpose indicate that from approximately 190 to 340 acres of land will be required to provide space for the ash dumps resulting from 40 years of plant operation. The ash transport and disposal system considered assumes hydraulic and pneumatic conveying of ash and spent catalyst, from the various sources to separating and holding tanks located at the disposal area. Decanted water would be recycled. Moist ash accumulated in the tanks would be carried, after drainage, by belt conveyor to an unloader-stacker which would distribute it onto dump piles, with the assistance of a bulldozer to compact the piles and maintain formation. Total cost of ash disposal area equipment of the capacity required for a unit coal synthine plant operating on Illinois coal, (from 460 to 810 tons of ash per day) is estimated at approximately $620,000 to

$920,000. This does not include ash collection equipment, which is normally covered in process plant costs. Total operating cost and fixed charges are estimated at approximately $400 to $570 per day, or $0.040 to $0.057 per barrel of products. Each percent of total investment allowed as gross return would amount to about $17 to $25 per day, or to $0.0017 to $0.0025 per barrel of products.

In the coal synthine process, practically all ash appears in the gasifier (synthesis gas producer) and must be completely removed from the synthesis gas before it passes to the reactors. In coal hydrogenation fuel consumed in the power plant consists of coal, amounting to about 20 percent of total plant requirements, plus the coke from delayed coking of heavy oil from the hydrogenation process. The coke contains all of the ash in the coal fed to hydrogenation (about 50 percent of plant requirements). Assuming pulverized fuel firing of the power plant boilers and normal distribution of ash size between fine and coarse particles, about 45 percent of total solid waste will appear in the form of fly-ash in the stack gases from the power plant. Assuming that the plant is in a fairly isolated location, where fly-ash nuisance can be tolerated, it should be unnecessary to install collection and removal equipment. In this case the net tonnage of ash actually requiring disposal will be less than two-fifths as great as for the coal synthine process, resulting in capital and operating costs of solid waste disposal only about three-fifths as great as those stated above. However, if local authorities should require fly-ash removal, total ash disposal costs would be about three-fourths of those for coal synthine.

The estimated solid waste disposal plant investment and daily operating costs (exclusive of return on investment) for the various General Areas in Illinois, for both coal hydrogenation and coal synthine unit plants, are shown in the following tabulations:

Solid Waste Disposal - Illinois
Estimated Disposal Plant Investment
(As of March 31, 1950)

General Area	Hydrogenation(A)	Coal Synthine
Southeastern Grundy	$415,000	$622,000
La Salle-Grundy	443,000	686,000
Bureau-Putnam	460,000	743,000
Henry No. 6	512,000	913,000
Northern Knox	510,000	906,000
Marshall	448,000	693,000
Peoria	495,000	857,000
Fulton-Knox	511,000	908,000
Vermilion	489,000	836,000
Logan	506,000	891,000
Macon	495,000	858,000
Menard	479,000	805,000
Sangamon	499,000	871,000
Northern Christian	496,000	860,000
Southeast Montgomery	494,000	855,000
Macoupin	488,000	837,000
Madison	494,000	855,000
Bond	502,000	879,000
Clinton	497,000	866,000
Marion	500,000	872,000
Clay	496,000	859,000
Wayne	480,000	809,000
Jefferson	458,000	734,000
Washington	514,000	922,000
St. Clair	506,000	889,000
Randolph	508,000	901,000
Perry	484,000	820,000
Franklin	459,000	738,000
Jackson No. 5	493,000	849,000
Williamson	479,000	804,000
Saline	473,000	774,000

Note: (A) Assuming that removal of fly-ash from stack gases is not required.

Solid Waste Disposal - Illinois
Estimated Disposal Plant Operating and Fixed Costs
(As of March 31, 1950)

General Area	Hydrogenation(A) Per Day	Hydrogenation(A) Per Barrel	Coal Synthine Per Day	Coal Synthine Per Barrel
Southeastern Grundy	$224	$0.023	$403	$0.040
La Salle-Grundy	251	.025	443	.044
Bureau-Putnam	270	.027	476	.048
Henry No. 6	319	.032	565	.057
Northern Knox	317	.032	560	.056
Marshall	256	.026	446	.045
Peoria	305	.030	537	.054
Fulton-Knox	318	.032	561	.056
Vermilion	299	.030	526	.053
Logan	314	.031	554	.055
Macon	305	.031	537	.054
Menard	289	.029	510	.051
Sangamon	308	.031	543	.054
Northern Christian	305	.030	538	.054
Southeastern Montgomery	304	.030	535	.053
Macoupin	298	.030	526	.052
Madison	304	.030	535	.053
Bond	310	.031	548	.055
Clinton	306	.030	541	.054
Marion	309	.031	545	.055
Clay	305	.030	538	.054
Wayne	290	.029	511	.051
Jefferson	268	.027	472	.047
Washington	321	.032	568	.057
St. Clair	314	.031	553	.055
Randolph	316	.031	559	.056
Perry	294	.029	518	.052
Franklin	269	.027	474	.047
Jackson No. 5	303	.030	533	.053
Williamson	289	.029	509	.051
Saline	283	.028	493	.049

Note: (Á) Assuming that removal of fly-ash from stack gases is not required.

The operation of such a disposal installation may require a total of about 19 to 25 employes, including direct operating and maintenance wage earners and supervisors, with a proportionate allocation of indirect personnel.

Over-all Costs of Waste Disposal

The preceding discussion indicates that treatment of liquid process wastes may absorb practically all of the allowance for waste disposal included in the general process plant cost estimates. In such event, costs of solid waste disposal developed above are in addition to any general processing costs and must be added separately to the total cost of product.

At certain locations, however, the study of stream pollution indicates that considerably less than maximum waste treatment may be acceptable. In such case the saving in cost of liquid waste disposal presumably could be applied as a credit against the cost of handling solid wastes.

PROCESS COSTS

Basis of Estimates

Estimates of plant capital investment and operating costs follow for two synthetic liquid fuel processes both using coal as raw material, i.e., the hydrogenation process and the synthine process. These estimates are based on estimates prepared by the Bureau of Mines. Plant capital investments, as so prepared, have been adjusted by the Contractor, as explained later in the text, to changes and differences in basic costs of labor and material between the time of such estimates and the time of this report.

As noted in a preceding section, "Processes and Plant Requirements", the estimated plant construction costs and process costs developed in the following pages are intended primarily for use in comparing the relative desirability of different areas as potential plant locations. For this reason, they were based on the assumed use of certain improvements in process and equipment which are still in the development stage but which appear reasonably likely to be applicable by the time significant numbers of synthetic liquid fuels plants could be constructed. For plants constructed as of today, using only equipment and processes now commercially available in this country, basic requirements and costs could be considerably higher than the estimates given.

Process costs estimated herein, as of March 31, 1950, as directed by the Contracting Officer, have been limited to operating costs included in U.S. Bureau of Mines cost estimating procedure, rather than costs comprising "cost of service" or selling prices. The Bureau of Mines procedure includes an allowance of approximately 3 percent of plant investment for plant maintenance; 6-2/3 percent for depreciation; 1 percent for insurance and local, county, and state real estate taxes; and an allowance equivalent to 10 percent of direct labor, plant maintenance and operating supplies for general administrative and general office overhead (which includes the salaries and wages of the General Manager or Plant Manager and his immediate staff reporting directly to management); but they include no allowance for head office or top management costs, selling expenses, return on investment, or sales and corporate (including income) taxes. Costs of coal used in the process have been computed on a "captive mine" basis and as such do not include selling expenses or return on the initial investment. The cost of water has been estimated on the same basis. To show the effect of return on investment, estimates are included herein to show the total investment required by its component parts, and the amount per barrel required for each 1 percent gross return (before income taxes) on initial capital investment.

Operating costs shown herein are reported, as directed by the Contracting Officer, in dollars per barrel of total product irrespective of its composition. Estimates of the equivalent cost of gasoline and credits for sale of by-products were not considered necessary for the determination of the most desirable General Areas. Because the product grades and quantities are different for each process, the raw material and process selected in each General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, comparison of General Areas has been made on the basis of one raw material at a time, for each applicable process.

Coal Hydrogenation Process

Plant Capital Investment. Based on an estimate by the Bureau of Mines of a typical unit plant hereinafter described, the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Illinois using the coal hydrogenation process. The table below compares the Bureau of Mines estimate with the estimate for a unit plant in Illinois General Area No. 1, Southeastern Grundy (as an example).

Estimates of Plant Capital Investment
for a 10,000-barrel-per-day Unit Plant
using Coal Hydrogenation Process

Item	Bureau of Mines Estimate of Typical Unit Plant (A) As of First Quarter 1948	Adjusted Estimate of Unit Plant in Illinois General Area No. 1 As of Mar. 31, 1950
Plant Construction Cost	$80,974,000	$ 91,096,000
Interest during Construction	3,037,000	3,416,000
Depreciable Investment	$84,011,000	$ 94,512,000
Operating Capital	4,608,000	5,522,000
Total Investment	$88,619,000	$100,034,000

Note: (A) Taken at one-third of the Bureau of Mines estimate (R.I. 4564) for a 30,000-barrel-per-day plant.

The Contractor's estimates for all General Areas in Illinois are tabulated in Exhibit No. 57 by General Areas of Coal and Water Availability.

Bureau of Mines Estimate. For a 10,000-barrel-per-day coal hydrogenation unit, this survey has adopted a cost equal to one-third of the plant cost estimated as of the first quarter of 1948 by the Bureau of Mines (and reported in its publication R.I. 4564) for a 30,000-barrel-per-day plant at Rock Springs, Wyo. designed to convert Wyoming bituminous coal to synthetic liquid fuels in the proportions stated in the section of this report entitled "Processes and Plant Requirements."

Such a plant includes complete power generation facilities. The Bureau of Mines estimates for a 30,000-barrel-per-day plant represent the cost of an arbitrary production unit of substantially maximum efficiency; the actual cost of a plant of only 10,000 barrels daily capacity might be considerably greater per barrel of product. Construction costs and required total investment for a typical unit plant, as previously defined - i.e., one-third of the cost of a 30,000-barrel plant - are shown in Exhibit No. 58.

Adjusted Estimate for Illinois. Since estimates in this report of processing costs in Illinois are as of March 31, 1950, it is necessary to apply factors to the Bureau of Mines costs to convert them to cost levels prevailing as of that date.

Adjustment to cost levels of March 31, 1950 is shown in the following tabulation:

Conversion of Costs of 10,000-barrel-per-day Coal Hydrogenation Plant at Rock Springs, Wyo., From First Quarter 1948 to March 31, 1950 Price Basis

Process Units	Estimated Costs: Cost as of 1st Quarter 1948	As of March 31, 1950: Factor (%)	As of March 31, 1950: Cost
Material:			
Major Equipment	$19,498,000	114.4%	$22,306,000
Other Materials and Equipment	9,410,000	109.1	10,266,000
Subtotal	$28,908,000		$32,572,000
Field Construction Labor	7,863,000	112.2	8,822,000
Field Indirect Costs	3,960,000	112.2	4,443,000
Total Construction Costs	$40,731,000	112.5	$45,837,000
Overheads	9,950,000		11,179,000
Total Process Unit Costs	$50,681,000	112.5%	$57,016,000
Auxiliary Units			
Tankage	$ 1,670,000	112.5%	$ 1,879,000
Power Plant	12,083,000	112.5	13,593,000
Plant Utilities Distribution	8,573,000	112.5	9,645,000
General Plant Facilities	7,967,000	112.5	8,963,000
Total Auxiliary Units	$30,293,000	112.5%	$34,080,000
Total Plant	$80,974,000	112.5%	$91,096,000
Factor	100.0%		112.5%

Factors for conversion of cost levels from the first quarter of 1948 to March 31, 1950 have been derived as follows:

Major Equipment (Material):

Bureau of Labor Statistics index of wholesale prices of iron and steel:

As of March 1948	As of March 1950	Factor of Change
147.7	169.0	114.4%

Other Materials and Equipment:

Other Materials and Equipment may be grouped in three general classifications with costs reported in R.I. 4564 (for a 30,000-barrel-per-day plant) as below:

Building Materials	Thousands of Dollars	
Foundations	$ 1,815	
Structures and Supports	2,930	
Buildings	3,220	
Painting	178	
Total		$ 8,143
Piping		11,924
Other Materials		
Instruments	$ 1,985	
Electrical	3,326	
Insulation	764	
Other Miscellaneous	2,088	
Total		8,163
Total Other Materials and Equipment		$28,230

The factor of conversion used for Other Materials and Equipment is a weighted average of the indices of wholesale prices of Building Materials (Bureau of Labor Statistics) and of the cost of piping from the Contractor's Cost Bureau. The first index was weighted by the cost of Building Materials above and the second by the cost of Piping. Other Materials were considered to follow the weighted index of Building Materials and Piping. Computation of the factor used is shown below:

Basis	As of March 1948	As of March 1950	Factor of Change	Weighting (Cost in $1,000's) Amount	Product
BLS Index, Wholesale Price of Building Materials	193.1	194.2	100.6%	$ 8,143	$ 8,192
Wholesale Price of Seamless Pipe:					
8 in.	$1.445	$1.664			
10 in.	1.775	2.041			
12 in.	2.321	2.662			
Total Pipe	$5.541	$6.367	114.9%	$11,924	$13,701
Total and Average			109.1%	$20,067	$21,893

Field Construction Labor:

Average of Bureau of Labor Statistics' union wage scales for selected building trades (giving building laborers a weight of three and skilled crafts a weight of one):

City	As of 4/1/48	As of 4/3/50	Factor of Change
Butte	$1.872	$2.067	110.4%
Denver	1.832	2.073	113.2
Salt Lake City	1.667	1.886	113.1
Average			112.2%

Field Indirect Costs:

This item, estimated as a percentage of labor costs, uses the conversion factor for labor.

Total Plant Costs:

The weighted average factor of total construction costs is obtained by dividing costs of March 31, 1950 by costs as of the first quarter of 1948. This factor is used for total process units and for all auxiliary units. Overheads are the difference between total process units and total construction cost.

No adjustment of costs for change in location from Rock Springs, Wyo., to the General Areas in Illinois has been made as such an adjustment is considered to be within the range of accuracy of the original estimate.

Interest during construction (shown in Exhibit No. 57) was estimated according to Bureau of Mines practice described as follows in R.I. 4564:

"It is estimated that 4 years will be required to construct such a plant. The interest on capital expenditures during construction is calculated at 2-1/2 percent. Expenditures are estimated at 10 percent of the total cost of the plant the first year, 20 percent the second, 30 percent the third, and 40 percent the fourth. It may be expected that some units will be completed and production begun by the end of the third year of construction. Under this financing schedule, interest amounts to approximately 3.75 percent of the plant cost".

Operating Capital was estimated for one plant in each General Area as shown in Exhibit Nos. 57 and 59. The method used was that of the Bureau of Mines as described in its R.I. 4564:

"In determining the amount of operating capital required, it is assumed that the plant will reach designed production within its first year of operation. It is expected that limited plant operation will begin at the end of 3 years' construction, and that construction and operation will be carried on simultaneously during the fourth year. It is expected that the average production rate during this period will be approximately 50 percent of full normal production. Similarly, it is assumed that consumption of raw material will be 25 percent of normal for the first 6 months and 100 percent for the last 6 months. The raw materials include coal, catalysts, and water. Operating capital must cover the cost of the initial 30-day supply of coal, raw materials, consumed during the first 6 months of operation, labor, maintenance, and all other operating costs except fixed charges. Fixed charges are not assessed until construction is completed; interest during construction is treated as a part of total plant cost. Operating expenses during the second 6 months will be financed from the sale of products made during previous operations."

In estimation of operating capital, the Contractor has included in the inventory prices of coal and water an allowance for return on investment in coal mines and water works.

More than one unit plant in any one of Areas Nos. 4, 5, 7, 26, or 27 or extension of the initial plant beyond 40 years' life would increase the operating capital requirement because of depletion of the cheap strip coal and the necessary inventory replacement by more expensive underground coal. Increases in estimates of operating capital caused by the use of all underground coal vary from $143,536 in General Area No. 26, Randolph, to $646,669 in General Area No. 5, Northern Knox as shown in the following table:

Increase in Operating Capital Requirement
for Additional Unit Coal Hydrogenation Plants
Using All Underground Coal
over Such Requirement for Initial Plant in Same Area

General Area Designation	Increase in Operating Capital
4. Henry No. 6	$156,922
5. Northern Knox	646,669
7. Peoria	611,655 (A)
26. Randolph	143,536
27. Perry	145,880 (B)

Note: (A) Some strip coal would be available for a second plant in this General Area and its use would result in an increase in operating capital (for a second plant only) of $340,917
(B) Same as (A) resulting in increase at $102,698

Operating Costs. Estimates of manufacturing costs based on estimates by the Bureau of Mines for the specific hydrogenation unit plant for which estimated construction costs have been stated (considered as a typical unit plant), are summarized in the first column of the following table:

Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Coal Hydrogenation Plant

Manufacturing Costs	Bureau of Mines Estimate of Typical Plant Per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Illinois As of March 31, 1950 Per Calendar Day	Per Barrel of Products
Direct Costs			
Direct Materials:			
Coal	$14,037	$24,040	$2.40
Catalysts and Chemicals	1,293	1,293	.13
Total Direct Materials	$15,330	$25,333	$2.53
Direct Labor:			
Wage Earners	$ 3,402	$ 3,442	$0.35
Supervision	510	516	.05
Total Direct Labor	$ 3,912	$ 3,958	$0.40
Plant Maintenance:			
Wage Earners	$ 3,858	$ 3,903	$0.39
Supervision	579	585	.06
Total Maintenance Labor	$ 4,437	$ 4,488	$0.45
Materials	2,218	2,496	.25
Total Plant Maintenance	$ 6,655	$ 6,984	$0.70
Payroll Overhead	$ 1,044	$ 1,056	$0.10
Operating Supplies	1,331	1,397	.14
Make-up Water	876	289	.03
Total Direct Costs	$29,148	$39,017	$3.90
Indirect Costs			
Indirect Labor	$ 927	$ 938	$0.09
Indirect Salaried Personnel	1,943	1,943	.20
Other Indirect Costs	3,079	3,289	.33
Total Indirect Costs	$ 5,949	$ 6,170	$0.62
Total Direct and Indirect Costs	$35,097	$45,187	$4.52
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,302	$ 2,589	$0.26
Depreciation	15,344	17,262	1.72
Total Fixed Costs	$17,646	$19,851	$1.98
Total Manufacturing Costs	$52,743	$65,038	$6.50
Less Coal and Make-up Water	14,913	24,329	2.43
Other Processing Costs (A)	$37,830	$40,709	$4.07

Note: (A) Other than coal and make-up water

The figures in the first column of the above table, adopted for this survey, are one-third of the manufacturing costs (as of the first quarter of 1948) estimated by the U.S. Bureau of Mines and reported in its publication R.I. 4564 for a 30,000-barrel-per-day plant (with complete power generation facilities) designed to convert Wyoming bituminous coal to products in proportions already stated. Coal and water quantities used in these estimates differ somewhat from those shown in the tabulation of basic data in the "Processes and Plant Requirements" section which, as stated, were based on the use of an average rather than a specific plant.

Preparation of the estimate based on that of the Bureau of Mines of daily operating costs of a typical unit plant used methods tabulated in Exhibit No. 60.

Operating costs estimated to apply as of March 31, 1950, in the General Areas of Coal and Water Availability in Illinois are summarized in the second column of the table. Costs of coal and make-up water are those for General Area No. 1, Southeastern Grundy, which Area was used as an example.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Areas of Coal and Water Availability in Illinois as of March 31, 1950 are tabulated in Exhibit No. 61.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Illinois as at Rock Springs, Wyo., (i.e., treated similarly to catalysts and chemicals, and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent on the estimated plant capital in the case of Illinois General Area No. 1, Southeastern Grundy, used as an example:

Incremental Costs for Each 1 Percent Gross Return on Initial Investment in Process Plant
Illinois General Area No. 1, Southeastern Grundy

Total Initial Capital Investment	$100,034,000
1 Percent Return on Above:	
Per Annum	$ 1,000,340
Per Calendar Day	$2,741
Per Barrel of Products	$0.274

Similar incremental costs for each 1 percent gross return on initial investment in Process Plant for all General Areas in Illinois are shown in Exhibit No. 57.

Additional plants in certain Areas previously mentioned would require increased operating capital in the different General Areas, the maximum increase being $646,669 in General Area No. 5, Northern Knox.

The incremental cost for each 1 percent gross return on this amount would be equivalent to $18 per day or $0.0018 per barrel of products which would not materially change the rates indicated in the foregoing table and Exhibit No. 57.

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost, and processing cost in each General Area, the calculations have been based on an (average) total daily raw material requirement of 98,000,000,000 Btu, for a typical coal hydrogenation unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the over-all efficiency of conversion, which in turn affects both daily Btu requirements and physical size of the plant (and hence construction and operating costs) varies with certain characteristics of the coal used as raw material, particularly with ash and moisture content and coal chemical reactivity.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in no case did the probable variation in coal quantity (as Btu), plant cost, or processing cost, due to individual coal characteristics, exceed plus or minus 10 percent of the mean. Only in the case of coals at the extreme upper and lower limits of the range designated as suitable for hydrogenation would indicated coal quantity and plant cost exceed by more than 10 percent the actual base figures used in the cost calculations above. In the large majority of cases, the variation should be a few percent only.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

Coal Synthine Process

Basis of Estimates. Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the United States and in Germany, the Bureau of Mines has in the course of preparation, estimates of construction and operating costs of a synthine plant on a commercial scale. Preliminary data from this study, for a plant producing 10,000 barrels of synthetic liquid fuels per day from Western Kentucky bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant, to be used as a basis of comparison for determining relative suitability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

Plant Capital Investment. Based on the preliminary estimates of the Bureau of Mines for a typical unit plant, the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Illinois using the coal synthine process. The table below shows figures as estimated by the Bureau of Mines and as adjusted for a unit coal synthine plant in Illinois General Area No. 1, Southeastern Grundy.

Estimates of Plant Capital Investment
for a Unit Plant
Using Coal Synthine Process

Item	Bureau of Mines Preliminary Estimate of Typical Unit Plant, As of Mar. 1, 1950	Adjusted Estimate of Unit Plant in Illinois General Area No. 1, As of Mar. 31, 1950
Plant Erection Cost	$81,805,000	$81,805,000
Interest during Construction	2,455,000	2,455,000
Depreciable Investment	$84,260,000	$84,260,000
Operating Capital	4,000,000	5,851,000
Total Investment	$88,260,000	$90,111,000

The Contractor's estimates for all General Areas in Illinois are tabulated in Exhibit No. 62 by General Areas of Coal and Water Availability.

Construction costs and required total investment for a coal synthine unit plant are shown in Exhibit No. 63, as estimated by the Bureau of Mines.

Adjusted Estimate for Illinois. For this survey, estimates of processing costs in Illinois are as of March 31, 1950. It is considered that any difference in cost levels prevailing between that date and the date of the Bureau of Mines estimate, March 1, 1950, is within the range of accuracy of the original estimate. No adjustment of costs for change of location from Caseyville, Ky., to the General Areas in Illinois has been made as such an adjustment is considered to be within the range of accuracy of the original estimate. Consequently, the Bureau of Mines estimate of Plant Erection Cost has been adopted as directly applicable to such a cost in the General Areas in Illinois.

Interest during Construction was estimated, as by the Bureau of Mines, at 3 percent of plant construction costs and is shown in Exhibit No. 62.

Operating Capital was estimated for one plant in each General Area as shown in Exhibits Nos. 62 and 64. In the absence of information as to the method employed in the Bureau of Mines estimate of costs of a typical unit plant using the synthine process the method followed for the hydrogenation process was used.

More than one unit plant in General Areas Nos. 4, 5, 7, 26, and 27 or extension of the initial plant beyond a 40-year life would increase the operating capital requirement because of depletion of the cheap strip coal and the necessary inventory replacement by more expensive underground coal. Increases in estimates of operating capital caused by the use of all underground coal vary from $144,897 in General Area No. 26, Randolph, to $786,727 in General Area No. 7, Peoria, as shown in the following table:

Increase in Amount of Working Capital Required for Additional Coal Synthine Plants Using All Underground Coal Above that Required for the Initial Plant

General Area Designation		Increase in Operating Capital
4.	Henry No. 6	$159,720
5.	Northern Knox	647,123
7.	Peoria	786,727(A)
26.	Randolph	144,897
27.	Perry	187,323

Note: (A) Some strip coal would be available for a second plant in this General Area and its use would result in an increase in Operating Capital (for a second plant only) of $692,800.

Operating Costs. Estimates of manufacturing costs, based on estimates by the Bureau of Mines, for the typical synthine unit plant for which estimated construction costs have been stated, are summarized in the first column of the following table:

Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Coal Synthine Plant

Manufacturing Costs	Bureau of Mines Preliminary Estimate of Typical Plant Per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Illinois As of March 31, 1950 Per Calendar Day	Per Barrel of Products
Direct Costs			
Direct Materials:			
Coal	$14,383	$30,904	$3.09
Catalysts and Chemicals	1,200	1,200	.12
Total Direct Materials	$15,583	$32,104	$3.21
Direct Labor:			
Wage Earners	$ 3,150	$ 3,132	$0.31
Supervision	473	470	.05
Total Direct Labor	$ 3,623	$ 3,602	$0.36
Plant Maintenance:			
Wage Earners	$ 3,897	$ 3,874	$0.39
Supervision	585	581	.06
Total Maintenance Labor	$ 4,482	$ 4,455	$0.45
Materials	2,241	2,241	.22
Total Plant Maintenance	$ 6,723	$ 6,696	$0.67
Payroll Overhead	$ 1,013	$ 1,007	$0.10
Operating Supplies	1,345	1,339	.13
Make-up Water	1,115	289	.03
Total Direct Costs	$29,402	$45,037	$4.50
Indirect Costs			
Indirect Labor	$ 963	$ 957	$0.10
Indirect Salaried Personnel	1,953	1,953	.20
Other Indirect Costs	2,930	2,909	.29
Total Indirect Costs	$ 5,846	$ 5,819	$0.59
Total Direct and Indirect Costs	$35,248	$50,856	$5.09
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,308	$ 2,308	$0.23
Depreciation	15,390	15,390	1.54
Total Fixed Costs	$17,698	$17,698	$1.77
Total Manufacturing Costs	$52,946	$68,554	$6.86
Less Coal and Make-up Water	15,498	31,193	3.12
Other Processing Costs (A)	$37,448	$37,361	$3.74

Note: (A) Other than coal and make-up water

The estimate, based on that of the Bureau of Mines of daily operating costs of a typical unit coal synthine plant, is developed by methods summarized in Exhibit No. 65.

Operating costs estimated to apply in the General Areas of Coal and Water Availability in Illinois, as of March 31, 1950, are summarized in the second column of the table. Costs of coal and make-up water are those for General Area No. 1, Southeastern Grundy, which Area was used as an example.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Areas of Coal and Water Availability in Illinois, as of March 31, 1950, are tabulated in Exhibit No. 66.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Illinois as at Caseyville, Ky., (i.e. treated similarly to catalysts and chemicals and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Initial Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent on the estimated plant capital in the case of Illinois General Area No. 1, Southeastern Grundy, used as an example:

Incremental Costs for each 1 Percent Gross Return on Initial Investment in Process Plant
Illinois General Area No. 1, Southeastern Grundy

Total Initial Capital Investment	$90,111,000
1 Percent Return on Above:	
Per Annum	$901,110
Per Calendar Day	$2,469
Per Barrel of Products	$0.247

Incremental costs for each 1 percent gross return on initial investment in process plant for all General Areas in Illinois are shown in Exhibit No. 62.

Additional plants in certain General Areas previously mentioned would require increased operating capital for such plants, the maximum increase being about $692,800, in General Area No. 7, Peoria.

The incremental cost for each 1 percent gross return on this amount would be equivalent to $19 per day, or $0.0019 per barrel of products which would not materially change the rates indicated in the foregoing table and Exhibit No. 62.

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost, and processing cost in each General Area, the calculations have been based on an (average) total daily raw material requirement of 126,000,000,000 Btu for a typical coal synthine unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the daily Btu requirements and physical size of the plant (and hence construction and operating costs) vary with certain characteristics of the coal used as raw material. The over-all Btu consumption increases with increasing moisture content of the coal, as received at the process plant, since additional Btu, over and above basic process requirements, must be consumed in evaporating surplus moisture to produce a coal of the requisite dryness for gasification. Furthermore, construction costs (dependent on physical size) of a synthine plant of given production capacity may vary through a maximum range of 20 percent, according to the rank of the coal available.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in the case of Btu requirements the maximum probable variation, over the entire range of coals included in the survey, from anthracite to the lowest grades of brown coal, is approximately plus or minus 10 percent of the mean. As stated above, there may be a variation in plant cost because of rank of coal of not more than plus or minus 10 percent from the mean. The base cost and Btu requirements for the typical plants used in the foregoing calculations differ somewhat from the actual mean. However, only the lower grades of lignites and brown coal give rise to Btu requirements and plant costs more than 10 percent greater than the base figures used. In the large majority of cases, the variation should be only a few percent.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

STRATEGIC CONSIDERATIONS

Based on studies made by the National Security Resources Board, it is believed that areas of industrial concentration of less than 5 square miles, or urban concentrations of less than 50,000 people, separated by about 10 miles of relatively open country, will be reasonably secure from atomic bomb attack under all circumstances expected to prevail.

The largest cities located within the General Areas of Illinois are as follows: Ottawa (pop. 16,951) in the LaSalle - Grundy Area; Kewanee (pop. 16,770) in the Henry No. 6 Area; Canton (pop. 11,910) in the Fulton - Knox Area; Danville (pop. 37,892) in the Vermilion Area; Lincoln (pop. 14,344) in the Logan Area; Decatur (pop. 67,801) in the Macon Area; Springfield, the State capital, (pop. 80,832) in the Sangamon Area; and Centralia (pop. 13,814) in the Marion Area. These census figures are a preliminary count of the 1950 census.

Of the several General Areas, Macon contains the city of Decatur, and the Sangamon Area contains Springfield, the State capital. These are possibly the least desirable in respect of strategic considerations, but even these appear reasonably secure under NSRB findings with regard to industrial and urban concentrations.

Possible targets in Illinois are the population concentrations, in Chicago, Rock Island, and Peoria with their railroad facilities. Also, to a lesser degree, there are concentrations around East St. Louis, plus locks, dams, and navigation facilities along the Mississippi, particularly around St. Louis. The Ohio River facilities, and the Illinois River locks, dams, and navigation facilities could also be considered possible targets. However, none of the foregoing concentrations directly involve any of the suitable General Areas.

The large power stations and transmission line networks in Illinois are dispersed and well set up to protect power supply from possible loss of any one or more plant units.

With due consideration for the factors indicated above, it is believed that the development of a new synthetic liquid fuels industry in Illinois could be so planned as to conform to the present published policies of the NSRB with regard to stragetic considerations.

PART VI

COMPARISON OF SUITABLE GENERAL AREAS

COMPARISON OF SUITABLE GENERAL AREAS

The relative merits of the 31 Suitable General Areas within the State of Illinois may be judged by a number of more or less independent criteria. Data therefor have been presented throughout this report and are in large part summarized in Exhibits Nos. 9, 67, 68, 69, and 70. As affecting the size of an industry which a General Area could support, the amount of available coal reserves is important, but it has little direct weight in comparison of the relative desirability of Areas for an initial unit plant in each.

The Suitable General Areas may be ranked according to estimated over-all construction costs of the initial unit plant and associated development in each General Area. Such estimates include the capital investment required for coal mining and process water supply facilities, the process plant itself, access transportation, products transportation (beyond the local marketing territory to the extent required), disposal of solid wastes from the process, plant-city development, and rental housing. The amounts, as tabulated in Exhibits Nos. 67 and 68, are exclusive of capital required for one-half of the dwelling units in the plant-city (assumed to be sold) and of the commercial facilities and domestic water supply (assumed to be self-supporting).

Another basis for relative ranking of the Suitable General Areas is by the estimated costs of products of the initial unit plant in each Area which, as shown in Exhibits Nos. 67 and 68, are exclusive of return on investment. Furthermore, the costs as shown make no allowance for that portion of the plant-city assumed ultimately to be sold, nor do they include operating costs of domestic water supply which are to be offset by water rents. The costs as shown are exclusive of operating costs of one-half of the dwelling units in the plant-city (assumed to be sold) and of the commercial facilities (assumed to be self-supporting). They also are exclusive of the costs of operation of rental housing and domestic water supply as these costs are estimated to be offset by a portion of the rentals paid by occupants of rental dwelling units and by water rents paid by consumers.

The relative ranking of the 31 Suitable General Areas on each of the foregoing bases is shown in the following tabulations for the hydrogenation and coal synthine processes, separately. The same tables indicate also the orders of relative desirability with respect to various components of the project construction costs and of the over-all costs per barrel of products.

Relative Orders of Desirability of
Suitable General Areas in Illinois
On Various Bases

HYDROGENATION PROCESS

Suitable General Area	Total Cost per Barrel of Products	Cost per Barrel of Products For				Total Capital Required	Capital Required For					Available Coal Reserves
		Coal	Water (Process)	Access Transportation	Waste Disposal		Coal Mining	Water (Process)	Process Plant	Access Transportation	Waste Disposal	
Peoria	1	1	4	7	12	1	15	3	1	11	17	12
Perry	2	2	18	8	8	8	7	12	2	9	11	4
Northern Knox	3	3	22	13	28	17	25	21	4	12	28	29
Randolph	4	4	12	1	21	3	1	9	3	1	27	15
Franklin	5	5	28	14	4	21	5	29	6	20	5	9
Saline	6	6	6	9	7	5	2	7	5	7	7	7
Northern Christian	7	7	20	29	13	24	22	22	7	29	19	6
Macoupin	8	8	23	23	14	18	13	23	8	23	12	1
Williamson	9	9	30	15	9	15	6	24	9	19	8	13
Southeastern Montgomery	10	10	29	31	15	30	24	30	10	31	15	3
St. Clair	11	11	13	2	22	10	9	10	11	2	25	5
Jefferson	12	12	24	25	5	22	3	28	12	26	4	10
Logan	13	13	10	16	23	14	11	16	13	16	26	25
Menard	14	14	21	17	10	13	14	15	14	21	9	17
Sangamon	15	16	15	26	24	16	16	19	15	25	22	2
Macon	16	15	31	27	25	31	20	31	16	28	18	24
Washington	17	17	16	30	29	26	19	18	17	30	31	23
Madison	18	18	5	18	16	7	12	5	18	18	16	11
Bond	19	19	19	10	26	23	23	20	19	8	24	22
Jackson No. 5	20	20	17	19	17	9	4	11	20	14	14	16
Marion	21	21	14	11	27	20	21	17	21	15	23	27
Henry No. 6	22	22	26	12	30	29	31	26	22	10	30	21
Clinton	23	24	7	3	18	19	28	13	23	3	21	8
Vermilion	24	23	27	20	19	28	27	27	24	17	13	14
Fulton-Knox	25	25	25	4	31	27	30	25	25	6	29	19
Wayne	26	26	11	21	11	12	26	8	26	13	10	18
Marshall	27	28	8	24	3	11	10	6	27	24	3	31
Clay	28	27	9	5	20	25	29	14	29	4	20	28
Southeastern Grundy	29	29	3	28	1	6	8	4	28	27	1	30
La Salle-Grundy	30	30	1	6	2	2	17	1	30	5	2	26
Bureau-Putnam	31	31	2	22	6	4	18	2	31	22	6	20

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Relative Orders of Desirability of Suitable General Areas in Illinois On Various Bases

COAL SYNTHINE PROCESS

Suitable General Area	Total Cost per Barrel of Products	Cost per Barrel of Products For				Total Capital Required	Capital Required For					Available Coal Reserves
		Coal	Water (Process)	Access Transportation	Waste Disposal		Coal Mining	Water (Process)	Process Plant	Access Transportation	Waste Disposal	
Peoria	1	1	4	7	17	1	15	3	1	11	17	12
Perry	2	2	18	8	11	8	7	12	2	9	11	4
Randolph	3	3	12	1	27	4	1	9	3	1	27	15
Franklin	4	4	28	11	4	16	5	29	5	20	5	9
Saline	5	5	6	12	7	3	2	7	4	7	7	7
Northern Christian	6	6	20	29	18	23	22	22	6	29	20	6
Macoupin	7	8	22	23	12	18	13	23	17	23	13	1
Williamson	8	7	30	13	8	13	6	24	7	19	8	13
Northern Knox	9	10	23	14	28	24	29	21	8	12	28	29
Southeastern Montgomery	10	9	29	31	13	29	24	30	9	31	15	3
St. Clair	11	11	13	2	23	10	9	10	10	2	25	5
Jefferson	12	12	24	25	5	17	3	28	11	26	4	10
Logan	13	13	10	15	24	15	11	16	12	16	26	25
Nenard	14	14	21	16	9	12	14	15	13	21	9	17
Sangamon	15	16	15	26	19	19	16	19	14	25	22	2
Macon	16	15	31	27	20	31	20	31	15	28	18	24
Washington	17	17	16	30	30	25	19	18	16	30	31	23
Madison	18	18	5	17	14	7	12	5	18	18	16	11
Bond	19	19	19	9	25	22	23	20	19	8	24	22
Jackson.No. 5	20	20	17	18	15	9	4	11	20	14	14	16
Marion	21	21	14	10	26	20	21	17	21	15	23	27
Clinton	22	23	7	3	21	21	27	13	22	3	21	8
Vermilion	23	22	26	19	16	27	26	27	23	17	12	14
Henry No. 6	24	24	27	20	31	30	31	26	24	10	30	21
Fulton-Knox	25	25	25	4	29	28	30	25	25	6	29	19
Wayne	26	26	11	21	10	14	25	8	26	13	10	18
Marshall	27	28	8	24	3	11	10	6	27	24	3	31
Clay	28	27	9	5	22	26	28	14	29	4	19	28
Southeastern Grundy	29	29	3	28	1	6	8	4	28	27	1	30
La Salle-Grundy	30	30	1	6	2	2	17	1	30	5	2	26
Bureau-Putnam	31	31	2	22	6	5	18	2	31	22	6	20

It can be noted that, although the relative orders of desirability of the General Areas as regards capital costs are essentially the same for initial plants for both types of processes, use of the coal synthine process as compared with hydrogenation would distinctly better the relative positions of Saline, Franklin, and Jefferson General Areas and hurt that of Northern Knox.

The effect of exhaustion of the limited reserves of cheaper strip minable coal in five General Areas and consequent necessity in the case of later plants of recourse to higher cost underground coal is shown by Exhibits Nos. 69 and 70. These exhibits show separately for the hydrogenation and synthine processes, respectively, total costs for an ultimate unit plant in such General Areas using underground coal only. Should only underground coal be used in all General Areas the order of relative desirability would change from that already determined on the basis of use of strip and underground coal (first plant) as follows:

Change in Relative Desirability for Ultimate
(All Underground Coal)
as Compared with Initial Unit Plants

Suitable General Area	Hydrogenation Process	Coal Synthine Process
Basis: Estimated Capital Required		
Peoria	1st place to 5th	1st place to 5th
Randolph	3rd place to 7th	4th place to 7th
Perry	8th place to 10th	8th place to 9th
Northern Knox	17th place to 28th	24th place to 28th
Henry. No. 6	29th place to 30th	No change
Basis: Estimated Cost of Products		
Peoria	1st place to 22nd	1st place to 22nd
Perry	2nd place to 4th	2nd place to 4th
Northern Knox	3rd place to 24th	9th place to 24th
Randolph	4th place to 8th	3rd place to 8th
Henry No. 6	22nd place to 25th	24th place to 25th

The relative orders of desirability of the 31 Suitable General Areas for initial and for ultimate unit plants, using underground coal only, are compared in the following tabulation:

Relative Orders of Desirability of Suitable General Areas in Illinois For Initial and Ultimate (Using Underground Coal Only) Unit Plants

HYDROGENATION PROCESS

Suitable General Area	Estimated Cost of Products		Estimated Capital Required	
	Initial	Ultimate	Initial	Ultimate
Peoria	1	22	1	5
Perry	2	4	8	10
Northern Knox	3	24	17	28
Randolph	4	8	3	7
Franklin	5	1	21	20
Saline	6	2	5	3
Northern Christian	7	3	24	23
Macoupin	8	5	18	17
Williamson	9	6	15	15
Southeastern Montgomery	10	7	30	29
St. Clair	11	9	10	9
Jefferson	12	10	22	21
Logan	13	11	14	14
Menard	14	12	13	13
Sangamon	15	13	16	16
Macon	16	14	31	31
Washington	17	15	26	25
Madison	18	16	7	6
Bond	19	17	23	22
Jackson No. 5	20	18	9	8
Marion	21	19	20	19
Henry No. 6	22	25	29	30
Clinton	23	20	19	18
Vermilion	24	21	28	27
Fulton-Knox	25	23	27	26
Wayne	26	26	12	12
Marshall	27	27	11	11
Clay	28	28	25	24
Southeastern Grundy	29	29	6	4
La Salle-Grundy	30	30	2	1
Bureau-Putnam	31	31	4	2

Relative Orders of Desirability of Suitable General Areas in Illinois For Initial and Ultimate (Using Underground Coal Only) Unit Plants

COAL SYNTHINE PROCESS

Suitable General Area	Estimated Cost of Products		Estimated Capital Required	
	Initial	Ultimate	Initial	Ultimate
Peoria	1	22	1	5
Perry	2	4	8	9
Randolph	3	8	4	7
Franklin	4	1	16	16
Saline	5	2	3	2
Northern Christian	6	3	23	23
Macoupin	7	5	18	18
Williamson	8	6	13	13
Northern Knox	9	24	24	28
Southeastern Montgomery	10	7	29	29
St. Clair	11	9	10	10
Jefferson	12	10	17	17
Logan	13	11	15	15
Menard	14	12	12	12
Sangamon	15	13	19	19
Macon	16	14	31	31
Washington	17	15	25	24
Madison	18	16	7	6
Bond	19	17	22	22
Jackson No. 5	20	18	9	8
Marion	21	19	20	20
Clinton	22	20	21	21
Vermilion	23	21	27	26
Henry No. 6	24	25	30	30
Fulton-Knox	25	23	28	27
Wayne	26	26	14	14
Marshall	27	27	11	11
Clay	28	28	26	25
Southeastern Grundy	29	29	6	4
La Salle-Grundy	30	30	2	1
Bureau-Putnam	31	31	5	3

Although unit costs for process water supply for full development of potential capacity in any General Area would, in the various General Areas, range from approximately 50 percent to slightly more than the unit costs for water for a single unit plant, the differences are insignificant as compared to total operating costs as stated (exclusive of return on investment). Such total costs include costs of coal, water, processing, transportation, housing, and waste disposal, subject to qualifications already discussed.

The figures presented are to be considered as indicative of average conditions within the respective General Areas. Depending upon actual plant locations, there will be some variation from the indicated orders of desirability. It is also possible that some plant locations, although satisfying most conditions, may be relatively less desirably situated with respect to other factors.

In evaluating the relative importance of the several bases of ranking relative order of desirability, the importance of the various criteria may be judged by average data for all Suitable General Areas of Illinois. The average estimated cost of construction and cost per barrel of products may be tabulated:

Average Estimated Cost of Products per Barrel and of Construction by Processes

(As of March 31, 1950)

	Hydrogenation Process		Coal Synthine Process	
	Amount	Percent	Amount	Percent
Estimated Cost of Products				
Coal	$1.770	29.88%	$2.286	37.30%
Water (Process)	.052	.88	.052	.85
Processing	4.071	68.73	3.736	60.97
Access Transportation	.001	.02	.002	.03
Product Transportation	-	-	-	-
Waste Disposal	.029	.49	.052	.85
Total	$5.923	100.00%	$6.128	100.00%
Estimated Capital Required				
	(x 1,000)		(x 1,000)	
Coal Mining	$ 6,675	5.48%	$ 8,602	7.42%
Water (Process)	3,493	2.86	3,493	3.01
Process Plant	99,580	81.70	89,530	77.21
Access Transportation	126	.10	126	.11
Product Transportation	-	-	-	-
Waste Disposal	487	.40	829	.72
Housing	11,529	9.46	13,375	11.53
Total	$121,890	100.00%	$115,955	100.00%

The order of desirability from the standpoint of estimated required capital differs somewhat from a ranking in terms of estimated cost of products, exclusive of return on investment. However, the range of variation in capital investment is less than one-quarter the range in cost of products. It appears, therefore, in determining the over-all relative order of desirability, cost of products would be of greater importance than required capital investment and is the basis which has been adopted.

Although, exclusive of return on investment, the cost per barrel of products is higher in every General Area for initial unit plants using the coal synthine process (see Exhibits Nos. 67 and 68), the cost spread between hydrogenation and coal synthine, which averages 20.5 cents per barrel, does not exceed 5.8 percent of the cost

by hydrogenation. Based on stated costs per barrel of products for initial unit plants, preceding tables show but two differences in the order of relative desirability between the hydrogenation and coal synthine processes; Northern Knox and Henry No. 6 Areas are third and twenty-second respectively for hydrogenation while, for coal synthine, they are ninth and twenty-fourth among the 31 Suitable General Areas.

The Suitable General Areas of Illinois may also be listed in terms of the daily production capacity which could be supported by available raw material reserves. Such a listing however, as in the following tabulation, has no bearing upon the relative desirability of the Areas for initial unit plants.

Daily Production Capacity of Synthetic Liquid Fuels Supportable over a 40-year Period from Available Coal Reserves
(Based upon alternative use of the two processes. Capacities as estimated are not additive.)

Suitable General Area	Thousands of Barrels per Day	
	Hydrogenation	Coal Synthine
Macoupin	280	218
Sangamon	240	187
Southeastern Montgomery	184	143
Perry	161	125
St. Clair	141	110
Saline	138	107
Northern Christian	137	106
Franklin	111	87
Clinton	110	86
Jefferson	87	68
Williamson	71	55
Madison	68	53
Pecria	67	51
Vermilion	55	43
Randolph	50	39
Jackson No. 5	50	39
Wayne	46	36
Menard	46	35
Fulton-Knox	38	29
Bureau-Putnam	34	26
Henry No. 6	31	24
Bond	31	24
Washington	31	24
Macon	28	21
La Salle-Grundy	27	21
Logan	27	21
Marion	22	17
Clay	20	15
Southeastern Grundy	16	13
Northern Knox	16	13
Marshall	10	8
Total	2,373	1,844

In determining the order of relative desirability of the Suitable General Areas of Illinois, the qualifications of each Area are to be judged not alone by factors which may be numerically evaluated but also on other bases not directly reflected in costs. Examples of such factors include power availability, strategic considerations, climate, and the like. Preceding discussion has, however, indicated in the case of Illinois that differences of such nature between the several Areas are minor and relatively insignificant.

Consideration of all the foregoing comparisons has resulted in the determination of orders of relative desirability of the 31 Suitable General Areas in Illinois, separately for each synthetic liquid fuels process, as follows:

Relative Desirability of Illinois Suitable General Areas

Hydrogenation Process			Coal Synthine Process		
Order	Area Name	Area No.	Order	Area Name	Area No.
1	Peoria	7	1	Peoria	7
2	Perry	27	2	Perry	27
3	Northern Knox	5	3	Randolph	26
4	Randolph	26	4	Franklin	28
5	Franklin	28	5	Saline	31
6	Saline	31	6	Northern Christian	14
7	Northern Christian	14	7	Macoupin	16
8	Macoupin	16	8	Williamson	30
9	Williamson	30	9	Northern Knox	5
10	Southeastern Montomgery	15	10	Southeastern Montomery	15
11	St. Clair	25	11	St. Clair	25
12	Jefferson	23	12	Jefferson	23
13	Logan	10	13	Logan	10
14	Menard	12	14	Menard	12
15	Sangamon	13	15	Sangamon	13
16	Macon	11	16	Macon	11
17	Washington	24	17	Washington	24
18	Madison	17	18	Madison	17
19	Bond	18	19	Bond	18
20	Jackson No. 5	29	20	Jackson No. 5	29
21	Marion	20	21	Marion	20
22	Henry No. 6	4	22	Clinton	19
23	Clinton	19	23	Vermilion	9
24	Vermilion	9	24	Henry No. 6	4
25	Fulton-Knox	8	25	Fulton-Knox	8
26	Wayne	22	26	Wayne	22
27	Marshall	6	27	Marshall	6
28	Clay	21	28	Clay	21
29	Southeastern Grundy	1	29	Southeastern Grundy	1
30	La Salle-Grundy	2	30	La Salle-Grundy	2
31	Bureau-Putnam	3	31	Bureau-Putnam	3

CONCLUSIONS

Conclusions drawn from this investigation and the determination of Suitable General Areas in Illinois for the production of synthetic liquid fuels are based upon presently available information. It should also be noted that the determination of the order of relative desirability for Suitable General Areas within a state such as Illinois does not at this stage:

(a) Constitute or propose a program for development;

(b) Imply any relationship to Suitable General Areas in other states; nor

(c) Reflect any allowance for new developments and additional future information which can be neither foreseen nor predicted.

Subject to such reservations, the following major conclusions are developed from this investigation and report:

1. Available information indicated no reserves of natural gas or oil shale in Illinois adequate for synthetic liquid fuels production. Coal is the only raw material meeting the qualifications of the survey.

2. The 31 Suitable General Areas in Illinois have the following orders of relative desirability for initial unit plants, based mainly on total cost per barrel of products, exclusive of return, for the hydrogenation and coal synthine processes, respectively. The number of the General Area is shown in parenthesis following its name.

Hydrogenation

1. Peoria (7)
2. Perry (27)
3. Northern Knox (5)
4. Randolph (26)
5. Franklin (28)
6. Saline (31)
7. Northern Christian (14)
8. Macoupin (16)
9. Williamson (30)
10. Southeastern Montgomery(15)
11. St. Clair (25)
12. Jefferson (23)
13. Logan (10)
14. Menard (12)
15. Sangamon (13)
16. Macon (11)
17. Washington (24)
18. Madison (17)
19. Bond (18)
20. Jackson No. 5(29)
21. Marion (20)
22. Henry No. 6 (4)
23. Clinton (19)
24. Vermilion (9)
25. Fulton-Knox (8)
26. Wayne (22)
27. Marshall (6)
28. Clay (21)
29. Southeastern Grundy (1)
30. La Salle-Grundy(2)
31. Bureau-Putnam (3)

Coal Synthine

1. Peoria (7)
2. Perry (27)
3. Randolph (26)
4. Franklin (28)
5. Saline (31)
6. Northern Christian (14)
7. Macoupin (16)
8. Williamson (30)
9. Northern Knox (5)
10. Southeastern Montgomery (15)
11. St. Clair (25)
12. Jefferson (23)
13. Logan (10)
14. Menard (12)
15. Sangamon (13)
16. Macon (11)
17. Washington (24)
18. Madison (17)
19. Bond (18)
20. Jackson No. 5 (29)
21. Marion (20)
22. Clinton (19)
23. Vermilion (9)
24. Henry No. 6 (4)
25. Fulton-Knox (8)
26. Wayne (22)
27. Marshall (6)
28. Clay (21)
29. Southeastern Grundy (1)
30. La Salle-Grundy (2)
31. Bureau-Putnam (3)

3. Coal deposits occur in 84 counties of central and southern Illinois, underlying an area of approximately 36,800 square miles. The total recoverable coal reserves considered for synthetic liquid fuels manufacture, have been estimated as of January 1, 1950, at 24,867,174,000 tons according to the specifications and procedures established for this survey. Of this tonnage, 17,234,643,000 tons (69.3 percent) are in Bed No. 6 and 6,794,206,000 tons (27.3 percent) are in Bed No. 5.

4. Of the total recoverable coal reserves considered, 301,870,000 tons or 1.2 percent are estimated to be suitable for strip mining.

5. The recoverable coal reserves of Illinois are distributed by counties as follows, in total and as contained within General Areas of Coal Availability:

Estimated Recoverable Coal Reserves Considered for Synthetic Liquid Fuels Manufacture by Counties (A)

(As of January 1, 1950)

County	Total Reserves (B) Thousands of Tons	Total Reserves (B) Percent of Total	Satisfactory Reserves Within the General Areas Thousands of Tons	Satisfactory Reserves Within the General Areas Percent of Total
Will	2,027	0.01%	2,027	0.01%
Grundy	171,804	.69	171,804	.76
La Salle	168,422	.68	160,732	.71
Bureau	99,285	.40	99,285	.44
Henry	106,577	.43	98,760	.44
Putnam	83,248	.33	83,248	.37
Kankakee	26,688	.11	26,688	.12
Livingston	5,322	.02	5,322	.02
Marshall	97,408	.39	61,139	.27
Stark	69,555	.28	69,555	.31
Knox	176,892	.71	170,885	.76
Peoria	453,076	1.82	453,076	2.01
McLean	4,392	.02	-	-
Tazewell	39,340	.16	-	-
Fulton	249,193	1.00	249,193	1.11
Vermilion	360,419	1.45	360,419	1.60
Logan	442,280	1.78	442,280	1.97
Schuyler	56,352	.23	-	-
Menard	457,033	1.84	457,033	2.03
Macon	258,120	1.04	258,120	1.15
Sangamon	1,799,404	7.23	1,799,404	8.00
Christian	1,399,817	5.63	1,384,985	6.16
Shelby	529,071	2.13	529,071	2.35
Edgar	207,749	.83	-	-
Montgomery	1,586,804	6.38	1,536,866	6.83
Macoupin	1,366,895	5.50	1,332,788	5.92
Greene	6,849	.03	-	-
Jersey	19,569	.08	-	-
Jasper	1,250	.01	1,250	.01
Effingham	7,521	.03	7,521	.03
Fayette	860,567	3.46	854,626	3.80
Bond	1,048,569	4.22	1,046,026	4.65
Madison	681,450	2.74	681,450	3.03
Lawrence	4,801	.02	-	-
Richland	1,944	.01	1,944	.01
Clay	374,935	1.51	374,935	1.67
Marion	140,023	.56	139,100	.62
Clinton	1,298,075	5.22	1,291,965	5.74
St. Clair	935,370	3.76	919,120	4.09
Wabash	12,443	.05	-	-
Edwards	3,399	.01	3,399	.02
Wayne	922,189	3.71	922,189	4.10
Jefferson	1,021,935	4.11	1,009,169	4.49
Washington	691,928	2.78	679,239	3.02

Estimated Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
by Counties (A)
(As of January 1, 1950)
(Concluded)

County	Total Reserves (B) Thousands of Tons	Total Reserves (B) Percent of Total	Satisfactory Reserves Within the General Areas Thousands of Tons	Satisfactory Reserves Within the General Areas Percent of Total
White	296,833	1.19%	-	-
Hamilton	1,473,142	5.92	-	-
Franklin	1,118,833	4.50	1,102,191	4.90%
Perry	1,070,101	4.30	1,070,101	4.76
Randolph	325,119	1.31	325,119	1.44
Gallatin	566,479	2.28	549,704	2.44
Saline	1,118,336	4.50	1,114,948	4.96
Williamson	545,239	2.19	545,239	2.42
Jackson	103,102	.41	103,102	.46
Total	24,867,174	100.00%	22,495,017	100.00%

Note: (A) Based on the specifications and procedures established for this survey.
(B) Before elimination of tonnage in unsatisfactory areas.

6. The recoverable coal reserves of Illinois are distributed by beds as follows, in total and as contained within General Areas of Coal Availability:

Estimated Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture,
by Beds
(As of January 1, 1950)

Coal Bed	Total Reserves (A) Thousands of Tons	Total Reserves (A) Percent of Total	Satisfactory Reserves Within the General Areas Thousands of Tons	Satisfactory Reserves Within the General Areas Percent of Total
Davis & Willis	7,545	0.03%	-	-
No. 2	568,643	2.29	560,826	2.49%
No. 5	6,794,206	27.32	5,778,343	25.69
No. 6	17,234,643	69.31	15,929,980	70.82
No. 7	262,137	1.05	225,868	1.00
Total	24,867,174(A)	100.00%	22,495,017	100.00%

Note: (A) Before elimination of tonnage in unsatisfactory areas.

7. The total coal reserves within the 31 Suitable General Areas of Illinois and the amounts available after elimination of secondary reserves in excess of primary reserves are estimated to be:

Estimated Coal Reserves Available for Synthetic Liquid Fuels Manufacture in the 31 General Areas After the Elimination of Excess Secondary Reserves (A)
(As of January 1, 1950)

Suitable General Area	Satisfactory Reserves Within the General Areas(B) Thousands of Tons	Percent of Total	Available Reserves Thousands of Tons	Percent of Total
Macoupin	1,866,874	8.30%	1,866,874	12.16%
Sangamon	1,799,404	8.00	1,612,940	10.50
Southeastern Montgomery	2,513,364	11.17	1,220,676	7.95
Perry	1,048,692	4.66	1,022,846	6.66
St. Clair	919,120	4.09	919,120	5.98
Northern Christian	1,287,199	5.72	899,764	5.86
Saline	1,664,652	7.40	801,624	5.22
Clinton	1,291,965	5.74	726,830	4.73
Franklin	1,015,719	4.51	673,788	4.39
Jefferson	1,009,169	4.49	519,496	3.38
Madison	681,450	3.03	450,006	2.93
Peoria	453,076	2.01	443,432	2.89
Williamson	450,014	2.00	424,470	2.76
Vermilion	360,419	1.60	360,419	2.35
Randolph	325,119	1.45	325,119	2.12
Jackson No. 5	306,208	1.36	306,208	1.99
Menard	457,033	2.03	303,476	1.98
Wayne	925,588	4.11	289,496	1.89
Fulton-Knox	306,104	1.36	259,500	1.69
Bureau-Putnam	219,805	.98	219,805	1.43
Henry No. 6	217,734	.97	217,734	1.42
Bond	1,046,026	4.65	207,712	1.35
Washington	679,239	3.02	204,296	1.33
Macon	229,019	1.02	184,654	1.20
Logan	442,280	1.97	179,544	1.17
La Salle-Grundy	172,265	.77	172,265	1.12
Marion	139,100	.62	139,100	.91
Clay	385,650	1.71	123,022	.80
Northern Knox	113,974	.51	113,974	.74
Southeastern Grundy	104,196	.46	104,196	.68
Marshall	64,560	.29	64,560	.42
Total	22,495,017(A)	100.00%	15,356,946	100.00%

Note: (A) Based on the specifications and procedures established for this survey.
(B) After elimination of coal in unsatisfactory areas.

8. The 31 Suitable General Areas are estimated to contain available recoverable coal in the amount of 15,356,946,000 tons after elimination of excess secondary reserves which quantity, dependent upon the conversion process used, is equivalent to a total of from 26,935,000,000 to 34,631,000,000 barrels of synthetic liquid fuels.

9. It is probable that continued exploration and development of Illinois' coal resources will result in the discovery of additional reserves in areas for which there is not now sufficient information to permit the present estimation of reserves for this survey. Information available at the time of this survey indicates that, after an allowance of 3,267,000,000 tons of coal for future commercial requirements (50 years production at the 1948 rate of production of 65,340,000 tons annually), sufficient coal reserves are available to supply, for a 40-year period, synthetic liquid fuels capacity amounting, as a maximum, to 2,373,000 barrels per day for the hydrogenation process or 1,844,000 barrels per day for the coal synthine process. These totals are subdivided by Suitable General Areas as follows:

Daily Production Capacity
(Thousands of Barrels)

Suitable General Area	Hydro-genation	Coal Synthine
Macoupin	280	218
Sangamon	240	187
Southeastern Montgomery	184	143
Perry	161	125
St. Clair	141	110
Saline	138	107
Northern Christian	137	106
Franklin	111	87
Clinton	110	86
Jefferson	87	68
Williamson	71	55
Madison	68	53
Peoria	67	51
Vermilion	55	43
Randolph	50	39
Jackson No. 5	50	39
Wayne	46	36
Menard	46	35
Fulton-Knox	38	29
Bureau-Putnam	34	26
Henry No. 6	31	24
Bond	31	24
Washington	31	24
Macon	28	21
La Salle-Grundy	27	21
Logan	27	21
Marion	22	17
Clay	20	15
Southeastern Grundy	16	13
Northern Knox	16	13
Marshall	10	8
Total	2,373	1,844

10. No coals of Illinois are classified as not amenable to hydrogenation, since reported analyses uniformly show fixed carbon contents of less than 69 percent (Maf basis).

11. Cleaning of Illinois coals as necessary to supply merchantable coal to synthetic liquid fuels plant would produce, per unit plant, approximately 1,690 tons of mine refuse per working day for a hydrogenation plant and approximately 2,173 tons for a coal synthine plant. Equivalent annual quantities of refuse would amount to about 270,400 and 347,680 cubic yards, respectively. No particular disposal problem would be presented.

12. Coals of the Illinois General Areas range from high-volatile A bituminous to high-volatile C bituminous in rank, with heating values, as received, ranging from 9,750 to 12,610 Btu per pound. Moisture, ash, and sulfur contents are:

Content of Selected Components
(Mine Sample, As-received Basis)

	Maximum	Minimum
Moisture	18.5%	4.3%
Ash	11.8	5.1
Sulfur	4.9	1.3

13. A limited number of petrographic assays of Illinois coals all indicate a "bright" petrographic type, in which anthraxylon and translucent attritus predominate. Since all of the coals of the 31 Suitable General Areas are closely similar in rank and in appearance and chemical composition to the coals on which petrographic assays were made, no substantial differences are expected in their adaptability to hydrogenation.

14. Estimated initial capital required in Illinois for coal mines, each to supply a single synthetic liquid fuels unit plant, is as follows:

Initial Capital Costs for Unit Plant Coal Supply
in Thousands of Dollars
(As of March 31, 1950)

Suitable General Area	Hydrogenation		Coal Synthine	
	Underground	Strip	Underground	Strip
Saline	$5,957		$ 7,659	
Jefferson	5,972		7,680	
Jackson No. 5	5,979		7,683	
Franklin	6,048		7,776	
Williamson	6,158		7,917	
Perry	6,336	$6,328	8,148	$8,136
Southeastern Grundy	6,428		8,264	
Randolph	6,484	4,905	8,340	6,306
St. Clair	6,516		8,376	
Marshall	6,649		8,547	
Logan	6,656		8,556	
Madison	6,656		8,556	
Macoupin	6,660		8,564	
Menard	6,668		8,572	
Sangamon	6,712		8,628	
La Salle-Grundy	6,783		8,723	
Bureau-Putnam	6,804		8,749	
Washington	6,829		8,778	
Macon	6,851		8,811	
Marion	6,867		8,828	
Northern Christian	6,909		8,887	
Bond	6,955		8,942	
Southeastern Montgomery	6,980		8,975	
Wayne	7,034		9,045	
Vermilion	7,048		9,064	
Clinton	7,074		9,099	
Clay	7,079		9,099	
Peoria	7,185	6,700	9,241	8,612
Fulton-Knox	7,357		9,464	
Northern Knox	7,889	7,012	10,143	9,016
Henry No. 6	8,010	6,484	10,296	8,338

15. Coal production costs, exclusive of selling expenses and return on investment, in the several General Areas of Illinois are estimated to be:

Coal Production Costs in Underground and Strip Mines
(As of March 31, 1950)

Suitable General Area	Coal Costs per Ton	
	Underground	Strip
Macoupin	$ 3.23	
Northern Christian	3.24	
Southeastern Montgomery	3.24	
St. Clair	3.39	
Randolph	3.39	$ 2.58
Perry	3.39	2.95
Franklin	3.39	
Logan	3.58	
Macon	3.58	
Menard	3.58	
Sangamon	3.58	
Williamson	3.58	
Saline	3.58	
Madison	3.81	
Jefferson	3.81	
Bond	3.83	
Washington	3.83	
Jackson No. 5	4.40	
Peoria	4.44	2.68
Fulton-Knox	4.44	
Vermilion	4.44	
Clinton	4.44	
Marion	4.44	
Henry No. 6	4.46	2.91
Northern Knox	4.46	2.68
Southeastern Grundy	5.46	
La Salle-Grundy	5.48	
Bureau-Putnam	5.48	
Marshall	5.48	
Clay	5.51	
Wayne	5.51	

16. The production costs of coal per barrel of products in synthetic liquid fuels unit plants are estimated to be:

Production Cost of Coal per Barrel of Products
(As of March 31, 1950)

Hydrogenation		Coal Synthine	
Suitable General Area	Cost	Suitable General Area	Cost
One Unit Plant: (A)			
Peoria	$1.23	Peoria	$1.58
Perry	1.28	Perry	1.64
Northern Knox	1.30	Randolph	1.75
Randolph	1.32	Franklin	1.81
Franklin	1.40	Saline	1.83
Saline	1.42	Northern Christian	1.88
Northern Christian	1.46	Williamson	1.89
Macoupin	1.47	Southeastern Montgomery	1.90
Williamson	1.47	Macoupin	1.90
Southeastern Montgomery	1.48	Northern Knox	1.91
St. Clair	1.51	St. Clair	1.95
Jefferson	1.56	Jefferson	2.00
Logan	1.63	Logan	2.10
Menard	1.63	Menard	2.10
Macon	1.64	Macon	2.11
Sangamon	1.65	Sangamon	2.12
Washington	1.71	Washington	2.19
Madison	1.74	Madison	2.23
Bond	1.74	Bond	2.23
Jackson No. 5	1.85	Jackson No. 5	2.38
Marion	1.94	Marion	2.50
Henry No. 6	1.97	Vermilion	2.56
Vermilion	1.99	Clinton	2.57
Clinton	2.00	Henry No. 6	2.59
Fulton-Knox	2.08	Fulton-Knox	2.68
Wayne	2.36	Wayne	3.03
Clay	2.37	Clay	3.05
Marshall	2.38	Marshall	3.06
Southeastern Grundy	2.40	Southeastern Grundy	3.09
La Salle-Grundy	2.43	La Salle-Grundy	3.12
Bureau-Putnam	2.43	Bureau-Putnam	3.13
Second Unit Plant: (A)			
Perry	$1.41	Perry	(C)
Peoria	1.67	Peoria	$2.49
Additional Unit Plants: (B)			
Perry	$1.47	Perry	$1.89
Randolph	1.51	Randolph	1.94
Peoria	2.03	Peoria	2.61
Northern Knox	2.14	Northern Knox	2.76
Henry No. 6	2.18	Henry No. 6	2.80

Note: (A) One unit plant in each Area, based on proportion of underground and strip used.
(B) Based on underground-mined coal. Costs in the other Areas not listed would be the same as for the first unit plant in those Areas which were based on underground-mined coal.
(C) All underground coal.

17. Ample water resources exist for the supply of sufficient synthetic liquid fuels plant capacity to process all available coal in 40 years. Water conservation works might, however, be required. The maximum water requirements are estimated at:

Maximum Process and Domestic Water Requirements for Complete Conversion of Available Coal Reserves Over a 40-year Period

	Cubic Feet per Second		
Suitable General Area	Process	Domestic	Total
Macoupin	376	65	441
Sangamon	323	56	379
Southeastern Montgomery	246	43	289
Perry	216	37	253
St. Clair	190	33	223
Saline	185	32	217
Northern Christian	183	32	215
Franklin	150	26	176
Clinton	148	26	174
Jefferson	118	20	138
Williamson	95	16	111
Madison	91	16	107
Peoria	88	15	103
Vermilion	74	13	87
Randolph	67	12	79
Jackson No. 5	67	12	79
Wayne	62	11	73
Menard	60	11	71
Fulton-Knox	50	9	59
Bureau-Putnam	45	7	52
Henry No. 6	42	7	49
Bond	42	7	49
Washington	42	7	49
La Salle-Grundy	36	7	43
Logan	36	7	43
Macon	36	7	43
Marion	29	5	34
Clay	26	4	30
Southeastern Grundy	22	4	26
Northern Knox	22	4	26
Marshall	14	2	16
Total	3,181	553	3,734

18. Initial capital investment and annual operating costs, exclusive of return on investment, required for process water supply, each to serve a complete unit plant for synthetic liquid fuels, are estimated to be as follows in the 31 Suitable General Areas of Illinois:

Initial Capital Investment and Annual Operating Costs for Process Water Supply
(As of March 31, 1950)

Suitable General Area	Investment	Annual Operating Cost
La Salle-Grundy	$ 632,000	$ 75,020
Bureau-Putnam	687,000	83,570
Peoria	971,000	109,210
Southeastern Grundy	1,301,000	105,310
Madison	2,064,000	146,000
Marshall	2,090,000	163,500
Saline	2,556,000	163,220
Wayne	2,603,000	175,190
Randolph	2,705,000	178,510
St. Clair	2,796,000	176,620
Jackson No. 5	3,024,000	189,700
Perry	3,037,000	192,030
Clinton	3,595,000	165,010
Clay	3,616,000	169,920
Menard	3,671,000	201,370
Logan	3,783,000	173,790
Marion	3,829,000	179,150
Washington	3,897,000	181,530
Sangamon	3,961,000	184,270
Bond	4,019,000	193,550
Northern Knox	4,068,000	208,540
Northern Christian	4,165,000	197,610
Macoupin	4,245,000	207,210
Williamson	4,506,000	275,120
Fulton-Knox	4,581,000	229,970
Henry No. 6	4,664,000	238,100
Vermilion	4,945,000	236,010
Jefferson	4,984,000	228,900
Franklin	5,101,000	239,070
Southeastern Montgomery	5,226,000	251,520
Macon	6,955,000	321,710

19. Annual operating costs of domestic water supplies, exclusive of return on investment, as shown in the following table, are not chargeable to plant operations since it has been assumed that these costs would be paid for by the consumers living in the plant-cities. Capital investments and annual operating costs for these domestic water supplies have been estimated as follows:

Initial Capital Investment and Annual Operating Costs for Domestic Water Supply
(As of March 31, 1950)

Suitable General Area	Investment	Annual Operating Cost
La Salle-Grundy	$ 605,000	$ 57,050
Bureau-Putnam	605,000	57,050
Peoria	430,000	38,200
Southeastern Grundy	605,000	57,050
Madison	574,000	44,780
Marshall	605,000	57,050
Saline	659,000	47,630
Wayne	667,000	49,710
Randolph	685,000	50,390
St. Clair	701,000	50,150
Jackson No. 5	741,000	52,350
Perry	743,000	52,770
Clinton	840,000	48,140
Clay	844,000	48,780
Menard	854,000	54,380
Logan	872,000	49,660
Marion	881,000	50,550
Washington	893,000	50,970
Sangamon	903,000	51,470
Bond	913,000	52,970
Northern Knox	922,000	55,660
Northern Christian	939,000	53,730
Macoupin	953,000	55,470
Williamson	999,000	67,230
Fulton-Knox	1,011,000	59,350
Henry No. 6	1,026,000	60,800
Vermilion	1,075,000	60,390
Jefferson	1,081,000	59,150
Franklin	1,102,000	60,960
Southeastern Montgomery	1,124,000	63,080
Macon	1,425,000	75,190

20. Although local utilities could be expected to have adequate power available for plant construction purposes, plant operating power requirements might be more economically provided by generating facilities obtained from part of the project.

21. The costs of installing and operating, exclusive of return on investment, the necessary supplementary access transportation facilities for an initial synthetic liquid fuels unit plant in each Suitable General Area in Illinois are estimated:

Cost of Access Transportation Facilities
(As of March 31, 1950)

Suitable General Area	Investment	Annual Cost
Randolph	$ 0	$ 0
St. Clair	0	0
Clinton	0	0
Clay	3,500	88
La Salle-Grundy	4,000	100
Fulton-Knox	5,500	138
Saline	25,000	1,250
Bond	31,000	1,400
Perry	37,000	1,550
Henry No. 6	45,000	2,125
Peoria	46,500	2,163
Northern Knox	50,000	2,500
Wayne	59,500	2,863
Jackson No. 5	62,500	2,813
Marion	65,000	1,625
Logan	70,000	3,500
Vermilion	76,500	3,475
Madison	81,500	3,913
Williamson	92,000	2,300
Franklin	93,500	4,338
Menard	105,000	4,625
Bureau-Putnam	123,000	5,000
Macoupin	160,000	6,750
Marshall	184,000	8,850
Sangamon	200,000	10,000
Jefferson	226,000	10,350
Southeastern Grundy	254,000	12,600
Macon	255,000	12,125
Northern Christian	297,000	13,925
Washington	495,000	23,375
Southeastern Montgomery	757,500	36,125

22. The average straight-time hourly rate, as of March 31, 1950, payable in a synthetic liquid fuels unit plant in Illinois, is estimated at $1.72. Should a second unit plant be introduced within about 50 miles of the first plant it is possible that sufficient labor may not be available locally to staff such a plant and might necessitate increasing labor rates in order to attract workers from a distance.

23. On an average for the 31 Suitable General Areas of Illinois, the necessary plant-city for an initial unit synthetic liquid fuels plant would be expected to accomodate 6,725 persons for a hydrogenation project or 7,801 persons for a coal synthine project. The corresponding initial investment required for housing and community development would be $26,401,297 or $30,627,429, respectively, exclusive of domestic water supply.

24. The value of commercial facilities (assumed to be self-supporting) and of one-half of the dwelling units in the plant-city (assumed to be sold) plus a proportionate share of the cost of land and utilities is estimated at $14,871,869 for a hydrogenation unit project and $17,252,350 for a coal synthine unit project. The remaining net investments in rental housing and plant-city development would therefore be $11,529,428 and $13,375,079, respectively.

25. From the standpoint of motor fuel, the annual consumption (exclusive of aviation and military use) in Illinois, Wisconsin, and Minnesota for 1948 and as estimated for 1975 follows:

Annual Motor Fuel Consumption
in Illinois Marketing Territory
(Millions of Barrels)

Territory	1948	1975
Illinois	47.67	80.00
Wisconsin	20.77	31.38
Minnesota	19.55	30.86
Total Illinois Marketing Territory	87.99	142.24
Equivalent Number of Unit Synthetic Liquid Fuels Plants (Gasoline Output)	32	52

26. The proportion of various liquid fuel products specified for plants considered in this survey differs importantly from the distribution of actual product consumption in Illinois, Wisconsin, and Minnesota. At such time as large-scale development would be required, synthetic liquid fuels plants undoubtedly would be designed, since the processes are to a considerable extent flexible, to conform to the then existing demand pattern.

27. Liquid fuel requirements in Illinois are economically supplied by petroleum products at refinery prices as of June 1, 1950, of $4.314 and $4.614 per barrel, respectively, for the fuel product distributions specified for hydrogenation and coal synthine plants.

28. When synthetic liquid fuels are required, plants in the Illinois Suitable General Areas would be well located for the distribution of their products within the defined marketing territory.

29. No unusual methods would be required in Illinois for the inoffensive disposal of solid and gaseous wastes of synthetic liquid fuels plants.

30. The treatment of liquid wastes, before disposal, to meet any anticipated requirements is feasible at costs within allowances therefor made in the general process plant estimates.

31. Disposal of solid wastes from synthetic liquid fuels plants in Illinois is estimated to involve the following capital investments and daily operating costs (before return on investment) in the several Suitable General Areas of Illinois, assuming that fly-ash removal from stack gases is not required:

Estimated Costs of Solid Waste Disposal
(As of March 31, 1950)

Suitable General Area	Investment (Thousands)	Operating Cost (Per Day)
Hydrogenation Process:		
Southeastern Grundy	$415	$224
La Salle-Grundy	443	251
Marshall	448	256
Jefferson	458	268
Franklin	459	269
Bureau-Putnam	460	270
Saline	473	283
Williamson	479	289
Menard	479	289
Wayne	480	290
Perry	484	294
Macoupin	488	298
Vermilion	489	299
Jackson No. 5	493	303
Southeastern Montgomery	494	304
Madison	494	304
Peoria	495	305
Macon	495	305
Northern Christian	496	305
Clay	496	305
Clinton	497	306
Sangamon	499	308
Marion	500	309
Bond	502	310
Logan	506	314
St. Clair	506	314
Randolph	508	316
Northern Knox	510	317
Fulton-Knox	511	318
Henry No. 6	512	319
Washington	514	321

Estimated Costs of Solid Waste Disposal
(As of March 31, 1950)
(Concluded)

Suitable General Area	Investment (Thousands)	Operating Cost (Per Day)
Coal Synthine Process:		
Southeastern Grundy	$622	$403
La Salle-Grundy	686	443
Marshall	693	446
Jefferson	734	472
Franklin	738	474
Bureau-Putnam	743	476
Saline	774	493
Williamson	804	509
Menard	805	510
Wayne	809	511
Perry	820	518
Vermilion	836	526
Macoupin	837	526
Jackson No. 5	849	533
Southeastern Montgomery	855	535
Madison	855	535
Peoria	857	537
Macon	858	537
Clay	859	538
Northern Christian	860	538
Clinton	866	541
Sangamon	871	543
Marion	872	545
Bond	879	548
St. Clair	889	553
Logan	891	554
Randolph	901	559
Northern Knox	906	560
Fulton-Knox	908	561
Henry No. 6	913	565
Washington	922	568

32. Typical synthetic liquid fuels unit plants in Illinois (represented by the Southeastern Grundy General Area) would involve investments as follows:

Estimated Initial Investment for a Typical Plant
(As of March 31, 1950)

	Hydrogenation	Coal Synthine
Plant Erection Cost	$ 91,096,000	$81,805,000
Interest during Construction	3,416,000	2,455,000
Depreciable Investment	$ 94,512,000	$84,260,000
Operating Capital	5,522,000	5,851,000
Total Investment	$100,034,000	$90,111,000

33. Typical synthetic liquid fuels unit plants in Illinois (represented by the Southeastern Grundy General Area) would incur daily operating costs, exclusive of return on investment, as follows:

Estimated Daily Operating Costs of a Typical Plant
Exclusive of Return on Investment
(As of March 31, 1950)

Processing Costs	Hydrogenation	Coal Synthine
Direct Materials	$25,333	$32,104
Water	289	289
Other Direct Costs	13,395	12,644
Direct Costs	$39,017	$45,037
Indirect Wages and Salaries	$ 2,881	$ 2,910
Other Indirect Costs	3,289	2,909
Indirect Costs	$ 6,170	$ 5,819
Taxes and Insurance	$ 2,589	$ 2,308
Depreciation	17,262	15,390
Fixed Costs	$19,851	$17,698
Total Costs, Exclusive of Return on Investment	$65,038	$68,554
Less Coal and Make-up Water	24,329	31,193
Other Processing Costs	$40,709	$37,361

34. Development of a synthetic liquid fuels industry in Illinois could be planned to conform with presently published policies of the National Security Resources Board with respect to strategic considerations.

35. In the 31 Suitable General Areas of Illinois, the net capital required for the complete installation of a synthetic liquid fuels unit project, including the manufacturing plant, process water supply, rental housing, and mine and other incidental facilities, but exclusive of commercial facilities and domestic water supply for the plant-city (assumed to be self-supporting) and of one-half of the dwelling units (assumed to be sold), is estimated as follows:

Estimated Initial Net Capital Required for Synthetic Liquid Fuels Projects in Illinois (A)
(As of March 31, 1950)

Suitable General Area	Initial Net Capital (A)	
	Hydrogenation	Coal Synthine
One Unit Plant: (B)		
Peoria (C)	$118,889,000	$112,833,000
La Salle-Grundy	119,436,000	113,548,000
Randolph	119,644,000	113,619,000
Bureau-Putnam	119,655,000	113,814,000
Saline	119,845,000	113,559,000
Southeastern Grundy	119,961,000	113,927,000
Madison	120,366,000	114,407,000
Perry (C)	120,619,000	114,443,000
Jackson No. 5	120,719,000	114,581,000
St. Clair	120,726,000	114,700,000
Marshall	120,927,000	114,988,000
Wayne	121,729,000	115,984,000
Menard	121,933,000	115,921,000
Logan	122,020,000	116,062,000
Williamson	122,133,000	115,939,000
Sangamon	122,391,000	116,439,000
Northern Knox	122,408,000	116,929,000
Macoupin	122,446,000	116,422,000
Clinton	122,452,000	116,684,000
Marion	122,504,000	116,661,000
Franklin	122,546,000	116,260,000
Jefferson	122,598,000	116,322,000
Bond	122,599,000	116,743,000
Northern Christian	122,750,000	116,813,000
Clay	122,764,000	117,065,000
Washington	122,800,000	116,930,000
Fulton-Knox	123,818,000	118,178,000
Vermilion	123,856,000	118,056,000
Henry No. 6	124,091,000	118,653,000
Southeastern Montgomery	124,366,000	118,446,000
Macon	125,607,000	119,689,000

Estimated Initial Net Capital Required for
Synthetic Liquid Fuels Projects in Illinois (A)
(As of March 31, 1950)
(Concluded)

Suitable General Area	Initial Net Capital (A)	
	Hydrogenation	Coal Synthine
Second Unit Plant: (B)		
Perry	$120,727,000	(D)
Peoria	119,492,000	$114,072,000
Additional Unit Plants: (E)		
Perry	$120,773,000	$114,642,000
Randolph	120,800,000	114,578,000
Peoria	119,986,000	114,249,000
Northern Knox	123,925,000	118,445,000
Henry No. 6	124,872,000	119,236,000

Note: (A) Exclusive commercial facilities and domestic water supply for the plant-city assumed as self-supporting and one-half of the dwelling units assumed as sold to employes.

(B) Based on one unit plant in each Area using strip coal as far as available and underground-mined coal to complete the 40-year fuel requirement.

(C) All strip coal.

(D) All underground-mined coal.

(E) Based on underground-mined coal. Costs in the other Areas not listed would be the same as for the first unit plant in those Areas which were based on underground-mined coal.

36. Operating costs of synthetic liquid fuels unit projects in Illinois in dollars per barrel of products, exclusive of return on investment, are estimated as follows for the two processes considered in this survey:

Estimated Operating Costs in Dollars per Barrel of All Products, Exclusive of Return on Investment
(As of March 31, 1950)

Suitable General Area	Type of Coal Mining (A)	Cost per Barrel of Products (A) Hydro-genation	Coal Synthine
One Unit Plant:			
Peoria (B)	S	$5.361	$5.401
Perry (B)	S	5.432	5.485
Northern Knox (B)	S-U	5.458	5.758
Randolph (B)	S-U	5.476	5.595
Franklin	U	5.569	5.655
Saline	U	5.569	5.663
Northern Christian	U	5.620	5.726
Macoupin	U	5.633	5.742
Williamson	U	5.649	5.757
Southeastern Montgomery	U	5.656	5.765
St. Clair	U	5.664	5.785
Jefferson	U	5.722	5.853
Logan	U	5.783	5.938
Menard	U	5.791	5.945
Sangamon	U	5.801	5.959
Macon	U	5.832	5.989
Washington	U	5.865	6.042
Madison	U	5.879	6.063
Bond	U	5.893	6.078
Jackson No. 5	U	6.002	6.217
Marion	U	6.094	6.338
Henry No. 6 (B)	S-U	6.140	6.448
Clinton	U	6.148	6.409
Vermilion	U	6.161	6.419
Fulton-Knox	U	6.248	6.532
Wayne	U	6.509	6.870
Marshall	U	6.520	6.883
Clay	U	6.523	6.890
Southeastern Grundy	U	6.530	6.899
La Salle-Grundy	U	6.542	6.920
Bureau-Putnam	U	6.554	6.935
Second Unit Plant: (C)			
Perry	S-U	$5.566	(D)
Peoria	S-U	5.803	$6.305

Estimated Operating Costs in Dollars per Barrel of All Products, Exclusive of Return on Investment
(As of March 31, 1950)
(Concluded)

Suitable General Area	Type of Coal Mining (A)	Cost per Barrel of Products (A) Hydro-genation	Coal Synthine
Additional Unit Plants: (C)			
Perry	U	$5.624	$5.733
Randolph	U	5.657	5.777
Peoria	U	6.164	6.434
Northern Knox	U	6.304	6.605
Henry No. 6	U	6.343	6.655

Note: (A) S-U is strip and underground mining; U is underground-mined coal only; S is strip-mined coal only.

(B) These General Areas contain some coal reserves recoverable by strip operations. Capacity in excess of one plant for a period of 40 years would require the use of higher cost underground-mined coal.

(C) These costs obtained by adjustment of costs in first unit plants for the higher price of underground-mined coal.

(D) All underground coal.

37. The amounts required to yield 1 percent gross return on the net initial investment are estimated as follows:

Amount of Each 1 Percent Gross Return
On Initial Net Investment in Plant and Facilities
In Dollars per Barrel of Products
(As of March 31, 1950)

Suitable General Area	Type of Coal Mining (A)	Hydro-genation	Coal Synthine
First Unit Plant:			
Peoria (B)	S	$0.326	$0.309
Perry (B)	S	.331	.314
Northern Knox (B)	S-U	.336	.321
Randolph (B)	S-U	.328	.311
Franklin	U	.336	.319
Saline	U	.329	.311
Northern Christian	U	.337	.320
Macoupin	U	.336	.319

Amount of Each 1 Percent Gross Return
On Initial Net Investment in Plant and Facilities
In Dollars per Barrel of Products
(As of March 31, 1950)
(Concluded)

Suitable General Area	Type of Coal Mining (A)	Hydro-genation	Coal Synthine
First Unit Plant: (Concluded)			
Williamson	U	$0.335	$0.318
Southeastern Montgomery	U	.341	.325
St. Clair	U	.331	.314
Jefferson	U	.336	.319
Logan	U	.335	.318
Menard	U	.334	.318
Sangamon	U	.336	.319
Macon	U	.344	.328
Washington	U	.337	.321
Madison	U	.330	.314
Bond	U	.336	.320
Jackson No. 5	U	.331	.314
Marion	U	.336	.320
Henry No. 6 (B)	S-U	.340	.325
Clinton	U	.336	.320
Vermilion	U	.340	.324
Fulton-Knox	U	.339	.324
Wayne	U	.334	.318
Marshall	U	.332	.315
Clay	U	.337	.321
Southeastern Grundy	U	.329	.312
La Salle-Grundy	U	.327	.311
Bureau-Putnam	U	.328	.312
Second Unit Plant: (C)			
Perry	S-U	$0.331	(D)
Peoria	S-U	.328	$0.313
Additional Unit Plants: (C)			
Peoria	U	$0.329	$0.313
Randolph	U	.330	.314
Perry	U	.331	.314
Northern Knox	U	.340	.325
Henry No. 6	U	.342	.327

(See following page for footnotes)

Note: (A) S-U is strip and underground mining; U is underground-mined coal only, S is strip-mined coal only.

(B) These General Areas contain some coal reserves recoverable by strip operations. Capacity in excess of one plant for a period of 40 years would require the use of higher cost underground-mined coal.

(C) These returns obtained by adjustment of returns in first unit plants for the higher investments required for underground mining of coal.

(D) All underground-mined coal.

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